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OF THE

AMERICAN WELDING SOCIETY

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American Welding Society

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JOURNAL

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AMERICAN WELDING SOCIETY

ESTABLISHED 1919

JOURNAL

Volume 6 MARCH, 1927 Number 3

PROGRAM

ANNUAL MEETING

of the

AMERICAN WELDING SOCIETY

33 West 39th Street, New York, N. Y.

April 27, 28 and 29, 1927

All Sessions Start Promptly as Scheduled

WEDNESDAY, APRIL 27, 1927

Committee Meetings

All Members of Society are Welcome!

Morning

Gas Welding Committee, S. W. Miller, Chairman
9:30 a. m. to 12, Room 1101.

A review of progress; suggestions for desirable researches and method of carrying them out.

Electric Arc Welding Committee, H. M. Hobart, Chairman
9:30 a. m. to 12, 10th Floor.

Analysis and discussion of the tests results made by the welding committee of the Emergency Fleet Corporation to determine certain fundamentals in connection with Electric Arc Welding.

Afternoon

Annual Meeting, American Bureau of Welding, C. A. Adams, Director, 2:00 p. m. to 5 p. m., 10th Floor.

A review of progress made by various research committees of the American Bureau of Welding. Plans for future investigational activities. Election of Officers and Executive Committee.

THURSDAY, APRIL 28, 1927

Morning

Technical Session

9:30 a. m. to 12, Room 2, 5th Floor, E. H. Ewertz, Chairman.

Report of Tellers' Committee

A symposium of research activities in the welding field during the past three years.

1. C. A. McCune, American Chain Company.

THURSDAY MORNING—(*Continued*)

2. J. H. Deppeler, Metal & Thermit Corporation.

3. R. R. Moore, Chief Physical Testing Branch, War Department, Air Service, McCook Field.

4. J. J. Crowe, Air Reduction Sales Company.

5. J. W. Owens, Director of Welding, Newport News Shipbuilding & Dry Dock Company.

6. R. B. Fehr, Una Welding and Bonding Company.

7. D. H. Deyoe, General Electric Co.

Luncheon

It is planned to arrange a luncheon for members of the Society at the Engineers' Club. Reservations should be made in advance. Tickets at $2.00 each may be obtained from the Secretary.

Afternoon

Tehnical Session

2:00 p. m. to 5, Room 2, 5th Floor, E. M. T. Ryder, Chairman.

Symposium on Production Welding.

In order to indicate the wide field of application of welding, six or seven specific applications to production work have been selected representing the several welding processes. A series of short papers will be given, each dealing exhaustively with one specific application, including cost figures, design data, technique of welding, jigs, method of testing, products, etc. These papers include:

1. Production Welding of Stern Frames. J. H. Deppeler, Metal and Thermit Corporation.

2. Replacing Castings by Welded Structural Parts. J. F. Lincoln, Lincoln Electric Company.

3. Application of Arc Welding to Houses and Buildings. C. J. Holslag, Electric Arc Cutting and Welding Company.

4. Oxy-acetylene Welding of Furniture. Author to be announced later.

5. Resistance Welding Paper. Title and author to be announced later.

6. Applications of Welding in Automobile Manufacture. Author to be announced later.

Evening

Dinner Dance

6:30 p. m.

Following the precedent established last year, the Annual Dinner of the American Welding Society will be followed by a dance and, of course, all the ladies are especially invited to attend. The dinner-dance will be held at the Hotel Commodore. Plans include the banquet with a Presidential Address by President Farmer; the announcement of the election of new officers and some special entertainment features of interest to both ladies and members of the Society.

Reservations should be made in advance by applying to the

Secretary. Dinner tickets may be obtained from the Secretary at $6.00 each.

FRIDAY, APRIL 29, 1927

Morning

Board of Directors

9:30 a. m. to 12, 10th Floor.

Meeting of Board of Directors, American Welding Society

Appointment of Committee Chairmen and other Officers. Committee reports. Discussion of Section Activities. Plans for coming year.

Afternoon

Joint Pressure Vessel Committee

Members of the A. W. S. Interested in the Subject May Attend This Meeting

Meeting of Joint Pressure Vessel Committee of A. S. M. E. and A. B. W., E. H. Ewertz, Chairman

2:00 p. m. to 5, 10th Floor.

Review of progress made by Subcommittees on Tests and Procedure. Plans of investigational work.

Entertainment for Ladies

The Entertainment Committee is planning some entertainment features especially for the ladies who are registered at the meeting. Details will be announced at the time of registration.

ARE CONVENTIONS WORTH WHILE?

(Reprinted from Feb. 5, 1927, issue ELECTRICAL WORLD)

To leave one's business for a week and to spend a couple of hundred dollars, more or less, journeying to a distant city to attend a gathering of men engaged in the same line of business as one's self demands some compensating advantages. Some more powerful reason than "the good of the industry" must exist. Eliminating all altruistic considerations, we come down to the real question, "What good shall I get out of it?"

There are so many demands made on our time and purse that we would soon have no business at all, and no balance in the bank, if we did not safeguard our minutes and our money. Conventions are strictly business affairs, and whether one attends or not should be decided on business grounds. But is it possible to bring together in daily conference for four or five days several hundred men in the same industry as one's self and get no benefit from mingling with them? Of course, the best of the talks will be printed in the trade papers, but what we cannot get at home is the mental stimulus, as well as the practical suggestions for increasing one's business and one's profits, that one gets at a convention. The benefits are obtained not in the convention hall itself but in conversation at the dinner table, in the hotel lobby or wherever we meet other men. No one will deny that he would profit immensely by the opportunity to visit hundreds of factories and companies engaged in the same business as himself. We cannot possibly acquire in our own town and in a single lifetime the experience of hundreds of men in all parts of the United States.

At the convention we meet these men—manufacturers and operators—we see under one roof the latest products of a hundred factories, we chat with men who in a city far removed from our own are conducting a business similar to ours and who, because their customers can never be ours, are willing to tell us of methods that they have found to be successful

in conducting their business. Each day we pick up new ideas, and we return home with a clearer conception of the things we must do to increase our business and with a keener desire to do them. Compare the man who has just returned from the convention of his industry with the man who stays at home. Which man would you prefer to deal with—the man who is as well posted as though he had spent six months visiting factories and other companies' systems, or the stay-at-home whose knowledge is limited to what he learns from the salesmen who occasionally drop in on him and to information derived from manufacturers' catalogs?

ROGER A. LEA.

Cleveland, Ohio.

WELDING VERSUS RIVETING

To the Members of the American Welding Society:

There has been in the recent past a great deal of very animated discussion of the relative merits of fusion welding and riveting for the joining of metals. There will be more discussion—much more—in the near future. It seems, therefore, not inappropriate to urge upon the welding fraternity at this time the wisdom of moderation in their public discussions of this highly controversial subject.

The riveting process of joining metals is not going to immediately disappear from industry just because of the rapid expansion of fusion welding. Riveting is too well established with too many years of prestige behind it. Furthermore, there probably will always be certain applications where riveting is the most suitable. Let us, therefore, avoid acrimony in our discussions and, as engineers, stick to facts.

It is well to remember that the facts and the tangible evidence will speak for themselves, and that there is no need for presenting the welding side of the case in any other than a conservative, dignified manner born of the knowledge that in many fields it is certain to win simply because the law of the survival of the fittest is inflexible in its operation in the industrial world. That process will automatically be used in each case which proves to be the most satisfactory for that particular type of application when all the factors have been considered. Sentiment and heated arguments of a controversial character on the part of the proponents of the two methods will have little influence on the final result.

F. MALCOLM FARMER,
President.

February 23, 1927.

PLANS FOR FALL MEETING

As previously announced, the Fall Meeting of the American Welding Society will this year be held in Detroit, the dates selected for this meeting are September 19 to 23.

Arrangements have been made to hold the Annual Exposition on Welding on this occasion as a joint exhibition with that of the American Society for Steel Treating, who hold their Annual Meeting and Exposition in Detroit at the same time. The technical sessions and Annual Meeting Dinner of the American Welding Society will be held at the Book Cadillac Hotel, while the technical sessions of the A. S. S. T. will be held at the Statler Hotel. This combined exhibition will prove particularly advantageous, as it is expected some 75,000 people will see the various exhibits. It will also allow many of our members to see a number of important demonstrations and exhibits of an allied industry.

Every effort is being made to insure the success of the Fall Meeting. The Detroit Section will have charge of the arrangements for inspection trips and entertainment features.

BOUND VOLUMES OF JOURNAL

With the February issue of the JOURNAL there was distributed to each member an index of the various papers published in the 1926 Volume of the JOURNAL. In order to meet the demands of our membership for a permanent record of the Society's publication, there is each year bound a limited number of copies in attractive book form with black leather covers. These volumes are sold to members at $5.00 per copy and to non-members at $10.00 per copy. The Volume for 1926 included some very valuable papers on welding. A few of the subjects covered include: Aluminum Welding, Bronze Welding of Cast Iron Pipe, Under Water Cutting, Design of Dished Heads of Pressure Vessels, Design of Various Forms of Welded Joints, Building Machinery by Welding, Researches on Pressure Vessels, Fatigue Tests of Tanks, Replacing Castings with Welded Parts, Atomic Hydrogen Welding, Welding

by the Railroads, Non-destructive Tests for Welds, Pipe Line Welding, Pressure Vessel Welding, Resistance Welding, Structural Steel Welding, Welding of Tanks, and a large number of papers containing important test data. Orders for copies should be placed, at once, with the Secretary of the Society.

ANNUAL MEETING

There is given elsewhere in this issue the program for the Annual Meeting of the American Welding Society. Contrary to the usual custom, the business session has been eliminated and matters usually coming before this session distributed among other meetings. This has permitted the Meetings and Papers Committee to set aside more time for technical sessions.

Another unusual feature is the entertainment provided for the ladies. An outstanding event in this connection will be the Dinner Dance which will be held at the Commodore Hotel. A luncheon, bus trip and probably a matineé will also be arranged for the benefit of the ladies. Out of town members are urged to bring along their wives and daughters.

Two symposiums have been arranged which will prove of considerable interest to the entire welding fraternity. One of these will include brief reports of some of the research activities during the past three years of leading companies identified with the industry. Opportunity will be provided for discussion. The other symposium has been arranged to include about eight short papers on "Production Welding" in different industries by the various welding processes.

There will also be a number of committee meetings, including Electric Arc Welding, Gas Welding, American Bureau of Welding and a meeting of the Joint Research Committee on Pressure Vessels of the A. S. M. E. and A. B. W.

To Members of the American Welding Society.

Gentlemen:

I would like to call your attention to the need for technical articles for publication in the JOURNAL OF THE AMERICAN WELDING SOCIETY. These articles may be on any subject connected with welding and may be short or long providing it is of sufficient interest.

Undoubtedly there is much material in the way of technical data, experience, etc., which our members have available on specific applications, but which they feel is not of sufficient importance to voluntarily offer as a formal paper. We should welcome the submission of any material of this kind to the Meetings and Papers Committee for publication in the JOURNAL. It is desired that the editor have available, excess material at all times to take care of unexpected delays, so that our publication program may be maintained and the JOURNAL issued on time.

Attention is called to the fact that we would also welcome communications from members of the industry on timely subjects of interest to the welding fraternity. These may or may not be of a technical nature.

Very sincerely yours,
W. SPRAGEN,
Editor, JOURNAL.

NEW MEMBERS

For the Months of November, December, January, February

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C. J. Desillier, 54 Clay St., Cambridge, Mass.
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Boilermakers, Kewanee Boiler Company, Kewanee, Ill.
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Alan D. McCall, Salesman, Drummond McCall & Corporation, Montreal, Canada.

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SECTION ACTIVITIES

Philadelphia

A very interesting symposium on welding and riveting as applied to structural steel parts, was held under the auspices of the Engineers Club in cooperation with the Philadelphia Section of the American Welding Society on Monday, Feb. 21. A list of the addresses presented is as follows: "The Rational Design of Structural Steel Joints for Arc-Welded Connections," by A. M. Candy, Westinghouse Electric & Manufacturing Co., Pittsburgh; "This Is the Age of Riveted Steel," by A. F. Jensen, president of the Hanna Engineering Works, Chicago; "Arc Welding as Applied to Manufacturing," by J. F. Lincoln, vice-president of the Lincoln Electric Co., Cleveland, Ohio; "The Rivet," by J. C. Hanna, chief engineer, Hanna Engineering Works, Chicago; "Welding of Structural Steel," by W. L. Warner, General Electric Company, Schenectady, N. Y.

Nearly three hundred people were present and a lively discussion followed the presentation of the papers. Lantern slides were used by several of the authors to illustrate their remarks.

A meeting of the Structural Steel Welding Committee was held in Philadelphia on the afternoon preceding the above meeting.

The March meeting will be held on the 21st, at which time Mr. R. E. Chapman of the Philadelphia Derrick & Salvage Corporation will talk on "Underwater Cutting."

Boston

The March meeting of the Boston Section was scheduled for the 18th, at the plant of the General Welding & Equipment Company. Two addresses will be the main feature of the evening. These are: "A New Method for Speedy Oxy-Acetylene Production Welding Which Will Be Demonstrated on Heater Sections" and "Pressure City Gas Installations and Their Uses, and Their Practical and Economical Features."

Lunch will be served previous to the meeting. A good time is assured to everyone who will attend.

New York

A symposium on Resistance Welding was held on March 15 by the New York Section. Mr. H. W. Tobey, of the General Electric Company, Pittsfield, presented a review of the developments in the resistance seam welders and their applications in the Pittsfield plant of the General Electric Company. A large number of slides were shown as well as samples of resistance welded specimens and a transformer tank completely welded.

Mr. W. H. Gibb, of the Gibb Welding Machines Company, presented a review of some new developments in resistance welding machines, particularly for seam welding. Mr. W. Remington of the Thomson Electric Welding Company, Lynn, Mass., gave an interesting lecture on the application of resistance welding to the mass production of large wheels. All of these papers were illustrated by lantern slides and many technical points were brought up in the discussion.

Chicago

The March meeting of the Section was held on the 4th. Mr. J. J. Crowe, Air Reduction Sales Company, presented a moving picture of Locomotive Welding and an address on "Welding Rods."

Cleveland

The Cleveland Section held a meeting on Feb. 24, which packed

the auditorium of the Cleveland Engineering Society. Mr. J. B. Green, president of the Chicago Steel & Wire Company, presented for the first time to the public a film showing metal transfer across the arc. This film is particularly interesting from a scientific viewpoint. A number of very interesting questions were brought up in the discussion.

Western New York

The February meeting of the Western New York Section of the American Welding Society was held at the Hotel Statler on the 15th. Mr. Wilson of the Haynes Stellite Company presented a very interesting discussion of the application of stellite. Demonstrations were also given by Mr. Wilson on this subject. The meeting was attended not only by members of the local section but also by a large number of the various sections of the National Societies under the auspices of the Engineering Society of Buffalo.

Pittsburgh

Careful plans are being made to revive interest in the Pittsburgh Section. Two meetings have been scheduled for the remainder of the year, one on applications of welding in the structural field, by A. M. Candy of the Westinghouse Electric & Manufacturing Company on April 15 and the other on Thermit Welding on May 20. A meeting of the executive committee of the Pittsburgh Section was held on March 11, to which was invited Mr. W. Spraragen, technical secretary of the Society. A membership committee, consisting of the following gentlemen were appointed: F. S. Tate, J. A. Warfel, F. L. Rodgers, C. C. Peterson and H. D. Kelley. The cooperation of every member of the Pittsburgh Section is requested in order to make the two coming meetings a success.

EMPLOYMENT SERVICE BULLETIN

Opportunities.—The Society is glad to learn of desirable opportunities from responsible sources, announcements of which will be published wthout charge in the BULLETIN.

Services Available.—Under this heading brief announcements (not more than seventy-five words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period, names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Society's Office not later than the thirtieth of the month if publication in the following issue is desired. *ALL REPLIES should be addressed to the number indicated in each case and mailed to Society headquarters.*

POSITIONS VACANT

V-36. *Wanted at Once.* Electric Welder thoroughly experienced with use of G. E. arc welding machine, particularly for welding structural steel. In replying outline your experience and state salary desired and whether married or not.

V-37. Desire to secure foreman for electric welding department at our ship yard.

SERVICES AVAILABLE

A-56. Experienced welder desires position. Have had eight years' experience as an Oxy-Acetylene Welder of steel, cast iron, and brazing. Have worked for the Hoist & Body Company, Columbia Machine Company, Link Belt Company, Baker Iron Works and Southern Pacific Company. With each of the three latter companies I have worked from two to three years.

A-57. Electric Welder desires position. Have worked for Westchester Lighting Co., J. L. Harris, Welding Engineer and Contractor, and Electrolux Sewerl Company. Can furnish references.

COMMITTEE ON WELDED RAIL JOINTS

Progress Report No. 5—July, 1926

A Summary of Tests and Reports

Organization:

The American Electric Railway Association and the American Bureau of Welding* united in an authoritative investigation of various types of welded rail joints in commercial use through a thoroughly representative committee which was organized late in 1921. This committee has a membership of about sixty individuals, including Way Engineers of several of the larger street railway companies, representatives of manufacturers of welded joints and welding equipment, welding experts, scientists and testing experts.

Dr. G. K. Burgess, then head of the Division of Metallurgy, Bureau of Standards, and now Director of the Bureau of Standards, was elected chairman. E. M. T. Ryder, Way Engineer of the Third Avenue Railway System, was elected vice-chairman and W. Spraragen, secretary of the Division of Engineering, N. R. C., and the American Bureau of Welding, was appointed executive secretary. Inasmuch as it was impossible to have this large committee meet more than once or twice a year, the administration of the affairs of the committee was left in the hands of a small representative Executive Committee.

Relation of American Electric Railway Engineering Association:

About $24,000 was contributed by the American Electric Railway Association, interested manufacturers, and a number of the larger street railways. The Association is acting as treasurer for the funds. Expenditures are made upon authorization of the Executive Committee and the bills are countersigned by the secretary and the vice-chairman of the committee and by a member of the Executive Committee of the American Electric Railway Engineering Association.

Objects:

The primary object of the committee is to improve each type of welded rail joint rather than to make comparative tests on the relative merits of the different types of joints.

Progress Report No. 1:

In order to compile a summary of the "present state of the art," a questionnaire was prepared on five types of welded joints in commercial use (cast, butt, bar, electric seam and thermit) and members of the committee were circularized. Answers to the questionnaire were correlated and a progress report of 73 pages

*The Bureau is the welding research department of the American Welding Society and the Division of Engineering, National Research Council.

printed in May, 1922. Typical problems needing further investigation were also included in the report.

Preliminary Program:

It was agreed that the next step was to test out joints representing the "present state of the art" by testing joints of each type made by representative street railway companies and by the manfacturers. Tensile, drop, repeated impact, bend and conductivity tests were made on each type of joint. In order to distribute the work the Bureau of Standards made the conductivity, repeated impact and tensile tests and also metallurgical examinations. Purdue University made the bend and conductivity tests and the University of Illinois the drop tests.

Progress Report No. 2:

Progress Report No. 2 was published by the committee in March, 1924. It consists of seventy-two printed pages and includes information on the organization of the committee; instructions issued to railway companies for making up test joints for the committee; methods of procedure and results in making tensile, bend, drop and conductivity tests; data furnished by the makers of these joints; photographs of specimens broken by the various tests and the discussion of the report.

Progress Report No. 3:

The Third Progress Report of the Committee on Welded Rail Joints, published April, 1925, does not include any of the results previously reported in Progress Report No. 2. It contains findings of the committee, test data and other material of interest to the committee obtained since the publication of Progress Report No. 2. Specifically it includes the remainder of results on tensile, bending and drop tests made on specimens to determine the present state of the art. The first results obtained from the repeated impact testing machine, as well as preliminary tests on the telemeter, are recorded in the report. In addition, there is also included the report of the joint examination sub-committee which carefully examined macroscopically and microscopically broken specimens; and the report of the sub-committee on Development whose function it was to draw up a program to test out the variables which affect the quality of the seam welded type of joint. The report contains 136 printed pages.

Progress Report No. 4:

The Fourth Progress Report is devoted exclusively to the test data and findings of the committee in connection with the repeated impact tests made to determine the present state of the art. This report includes a description of the method of operation of the repeated impact testing machine, charts showing location of failure, number of blows necessary to cause this failure and photographs of the broken joints. The report includes also, discussions by sev-

eral individual members of the committee. It consists of 35 printed pages.

Progress Report No. 5:

This present pamphlet is the Fifth Progress Report of the Committee. It does not include any of the results previously reported in Progress Reports 2, 3 and 4. The report includes a series of shear test results made by the committee to develop a joint plate and method of welding, which would give a maximum area of cross section of soundly fused weld metal in the seams. The report also includes a program of additional investigations proposed by the committee and a description of some preliminary telemeter tests made to determine stresses in rail joints under conditions simulating various degrees of poor joints and also test joints subjected to blows from the repeated impact testing machine.

Shear Tests

This series of investigations was made to develop a joint plate and method of welding which would give maximum area of cross section of soundly fused weld metal in the seams of rail joints. Specimens were made up by welding 12-in. sections to fish plates in a 60-ft. Association Standard 7-in. girder rail. The distance between sections was sufficient to allow cutting by the Oxy-Acetylene torch. The length of the welded seam was 10 in. (1-in. space being left at each end). In order to simulate track conditions the welding was done with the rail placed on the floor.

Each section having a 12-in. fish plate welded by 10-in. seams was cut in half with a saw and from one of each set of three specimens representing the different variables a half-inch section was cut and etched and a photograph made of the face by the Bureau of Standards to indicate the quality of welding, the position of the weld metal and the penetration secured. Originally, it was planned to shear one-half of the section by placing in a compression machine and the other half was to be wedged off by means of a triangular wedge. On a trial test it was found that the area of fused metal could be readily obtained from the sheared section and therefore it was felt unnecessary to make the wedge test. A torch cut was made longitudinally along the center line of each fish plate in order to allow shearing of each seam separately and in order to make it possible to measure this shearing force. Five types of joint plates were selected for study as shown in Fig. 1 of this report.

The instructions shown in Progress Report No. 3 in regard to the variables are as follows:

Variables: Several selected types of fish plates shall be used. On each type there shall be employed the following methods.

a. Hand feed with a 9/32″ rod in one layer depositing 1½″ of rod per inch of seam.

b. Hand feed with 9/32″ rod depositing 3″ of rod per inch of seam.
c. Hand feed with 9/32″ rod depositing weld in two layers using 1½″ of rod per inch for each layer.
d. One 9/32″ rod in position.
e. One 9/32″ rod in position and rewelded with another 9/32″ rod laid in position on top of first weld.
f. Repeat "e" using third rod.
g. Metallic arc weld with 5/32″ rod one layer, same cross section as in "a."
h. Metallic arc weld with 5/32″ rod one layer having same cross section as "b."
i. Metallic arc weld with 5/32″ rod metal deposited in two layers each having same cross section as "c."

Numbering System

First: The letter P to denote specimens of this plate investigation.

Second: A number to designate the type of joint plate shown in Fig. 1, as follows:

1. Shoulder type.
2. Third Avenue type.
3. Boston type.
4. Spraragen type.
5. Rail Joint Co. type.

Third: A letter to denote the variable of welding, as:

A. Carbon arc, hand feed with a 9/32″ rod in one layer, depositing 1½″ of rod per inch of seam.
B. Carbon arc, hand feed with a 9/32″ rod in one layer, depositing as much metal as possible per inch of seam but not to exceed 3″ of rod per inch of seam.
C. Carbon arc, hand feed with a 9/32″ rod, depositing weld in two layers, using 1½″ of rod per inch for each layer.
D. Carbon arc, one 9/32″ rod in position.
E. Carbon arc, one 9/32″ rod in position and rewelded with another 9/32″ rod laid in position on top of first weld.
F. Repeat "E" using third rod.
G. Metallic arc weld, with 5/32″ rod one layer, same cross section as in "A."
H. Metallic arc weld with 5/32″ rod one layer having same section as "B."
I. Metallic arc weld with 5/32″ rod, metal deposited in two layers each having same cross section as "A."

Fourth: A number to distinguish the three similar specimens with a given joint plate and method of welding.

Thus, P1A1 denotes the shoulder type plate welded by using carbon arc, hand feed with a 9/32-in. rod in one layer depositing 1½-in. of rod per inch of seam, the first of three similar specimens.

Shear Test Results

Arrangements were made with Lehigh University to make these Shear Tests. The method employed in making the tests, measurement of area and the test results are given in Professor Fogg's report, which follows. In order to bring out these test results more clearly, two series of charts were prepared through the courtesy of the Third Avenue Railway System. One series shows the shear strengths of each seam per linear inch of seam. The record of each specimen is shown on the chart and the median values are joined by lines. The second series of diagrams shows the Displacement for various loadings of the test joints. In order to indicate

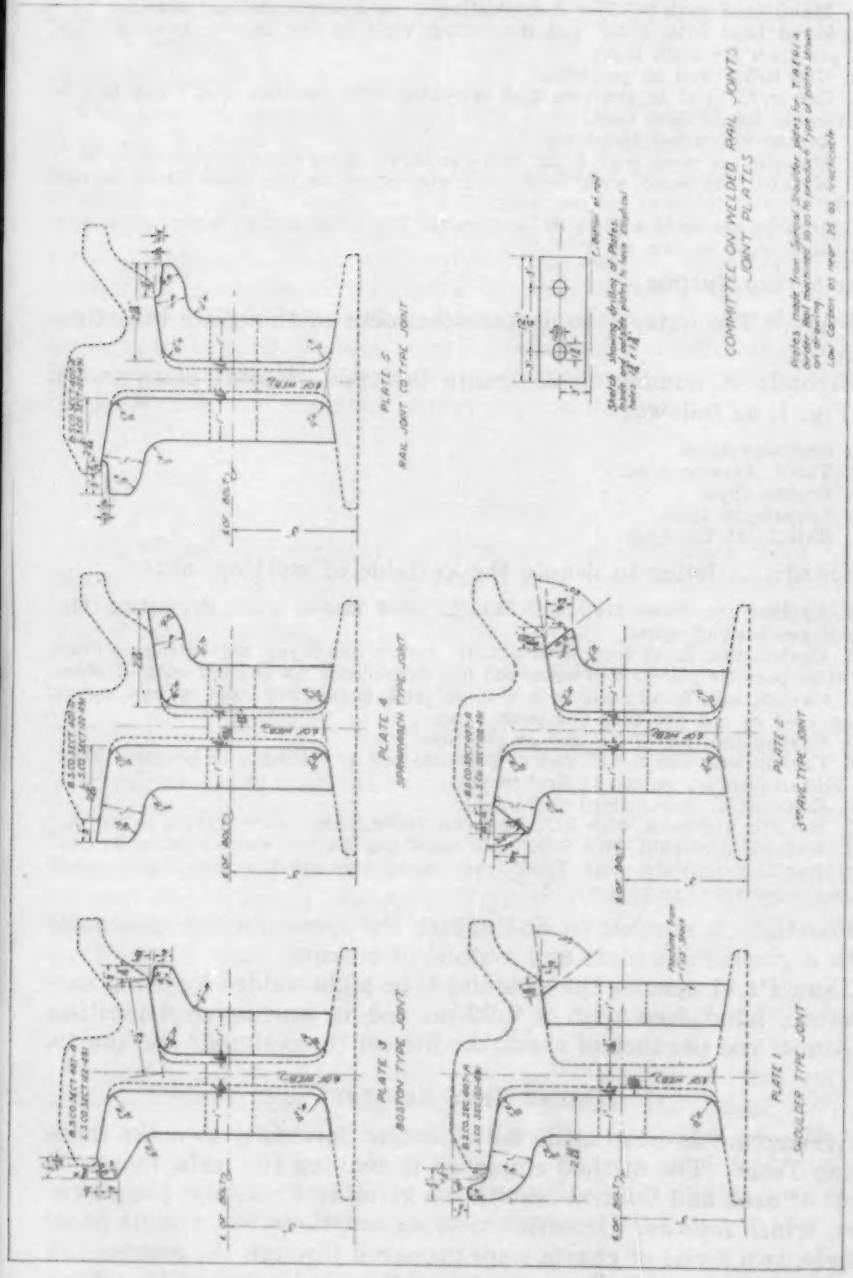


Fig. 1

the location of the weld metal for each type of joint plate and method of welding there are shown photographs of the etched sections of these test joints made by the Bureau of Standards.

ment for various loadings of the test joints. In order to indicate

Report on Longitudinal Shearing Tests of Rail Plate Welds

By R. J. Fogg,
Professor of Civil Engineering, Lehigh University,
October, 1926.

To the Committee on Welded Rail Joints.

Gentlemen:

The following is a report on the longitudinal shearing tests of welded rail plate specimens, delivered to the Fritz Engineering

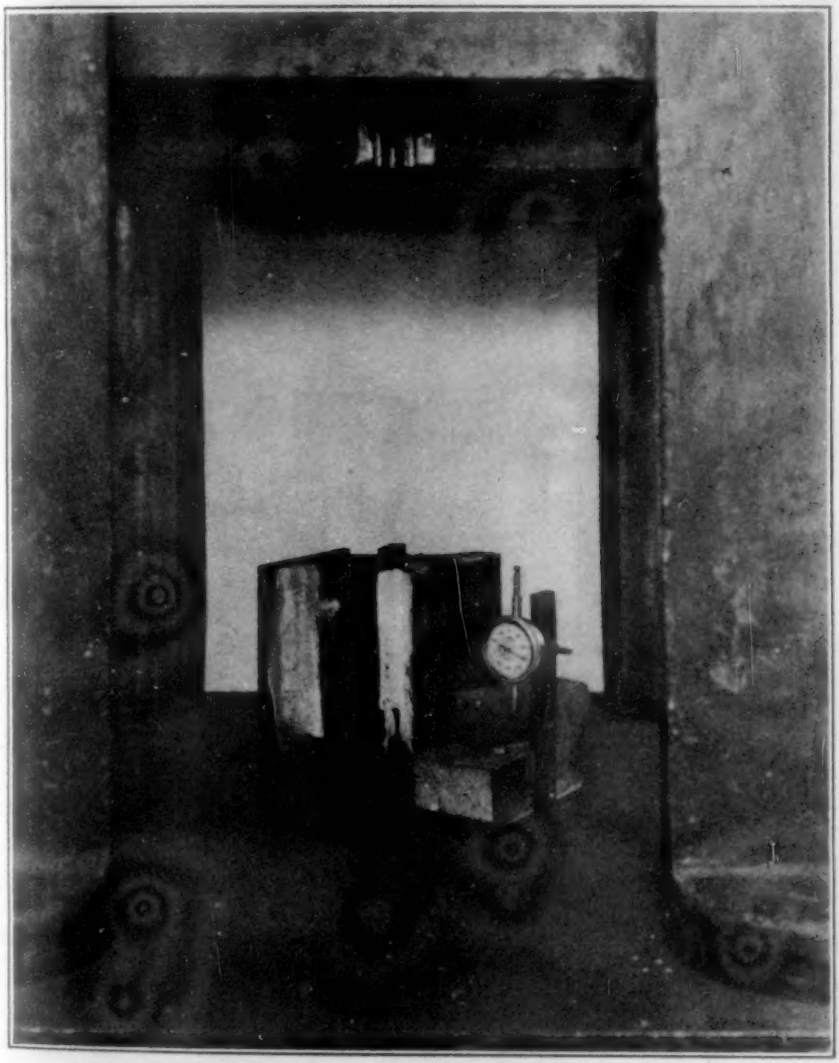


Fig. 2 Showing single specimen set up for test

Laboratory last spring. These tests have been made by M. O. Fuller under the direction of R. J. Fogg.

Number of Specimens

Of the 270 specimens delivered 135 were tested, this being the number settled upon by your committee. The tested specimens consisted of triplicate sets of five different types of rail plate arrangements (Fig. 4), each type having nine welding variables, presumably as indicated on page 66 of Progress Report No. 3, dated April, 1925. It should be noted that nine of the 270 specimens were found on delivery, to be imperfect and unsuitable for

Fig. 3. Showing double specimen set up for test

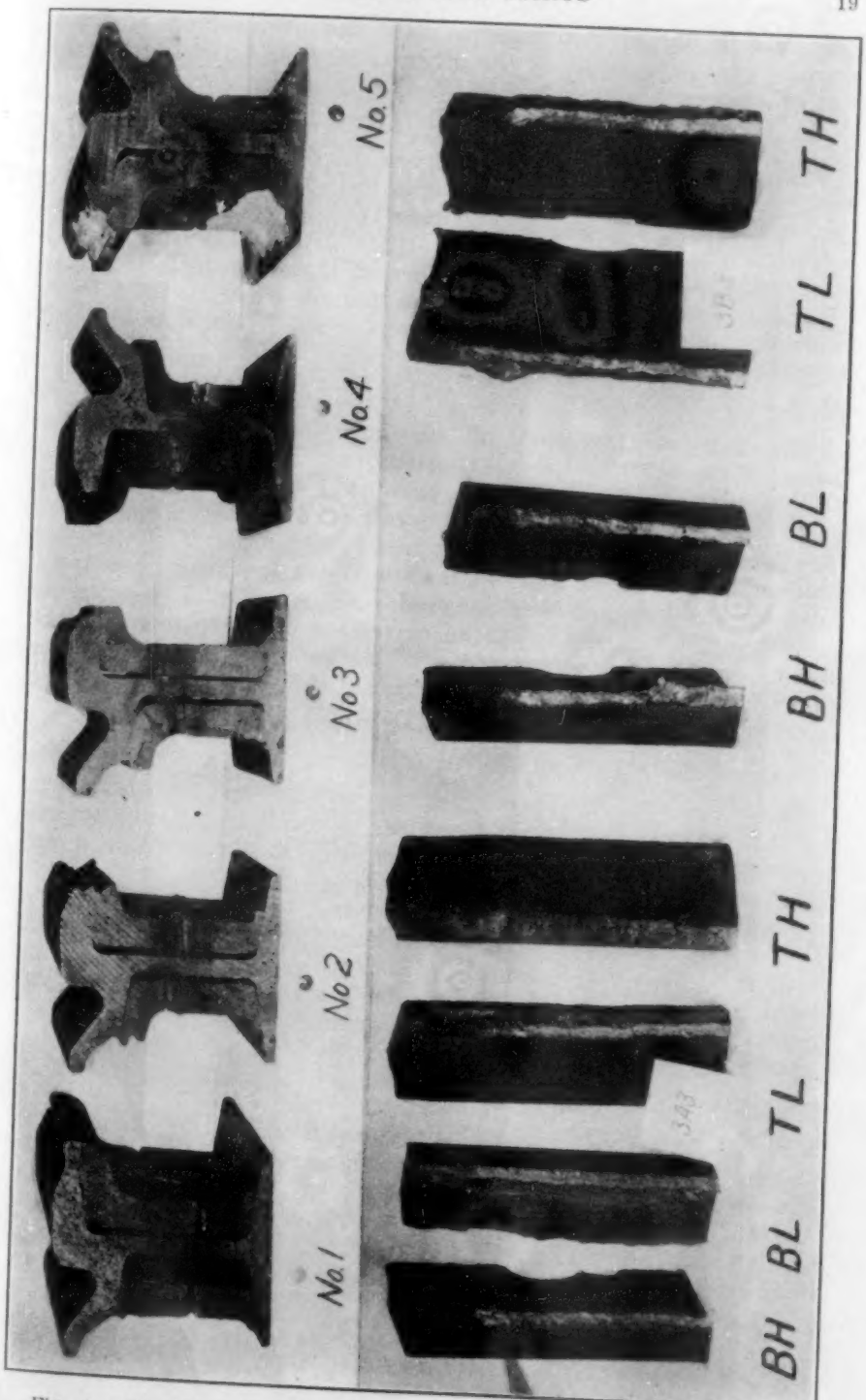


Fig. 4. Showing types of rail plate arrangements

Fig. 5. Showing typical fractures

testing. In one or two cases a plate had dropped off and was wired to the rail, while in the other cases the plates were either out of alignment or loose.

Type of Specimens

Fig. No. 4 shows a cross section of the five types of rail plate arrangements. Each specimen originally consisted of two plates welded to a rail. In some cases the specimens came in pairs, while in others they were single. (See Figs. No. 2 and No. 3.) Each plate was cut in halves (either at the laboratory or before shipment), lengthwise of the rail, so that for each specimen there were four pieces of plates, each piece being attached to the rail by only one seam.

Method of Testing

The plates were sheared off, one at a time, lengthwise of the seam. This was done by setting the rail upright on the bed of the machine and lowering the upper head of the machine onto a small block of hard steel, which was placed on top of the plates. The block was set practically against the seams so as to avoid a moment. Figs. No. 2 and No. 3 show the set-up before the upper head of the machine was lowered. An Ames dial, reading to 1/1000 of an inch, recorded the movement of the plates. Before testing, each seam was painted with plaster of paris or neat white cement, in order to detect stress cracks while the specimens were carrying load.

Tabular Results

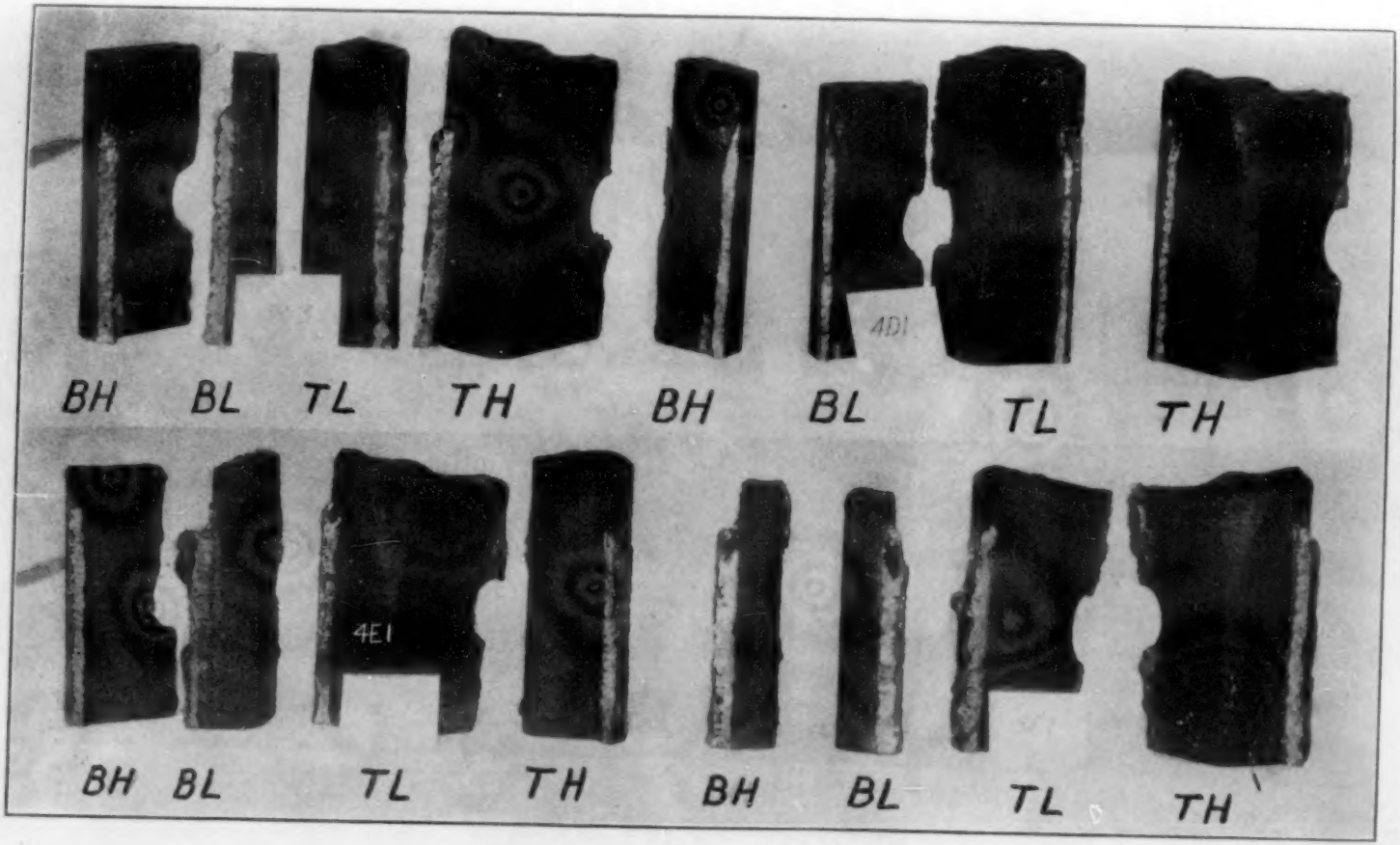
The tables show the location of the seams tested for each specimen; the area of the weld fracture; proportional limit load and maximum load. In the column following these loads the unit stress (lb./per sq. in.) is given. *It should be noted that a high unit stress does not imply a good weld, because a very small weld area divided into a low load may give a result which is higher than a large weld area divided into a high load.* The table also shows the appearance of the fractures, the load at first crack and the length of weld. The label given each specimen is the identification mark put on by your committee.

Typical Fractures and Graphs

Figs. Nos. 5, 6, 7, 8 and 9 show typical fractures for each type of welding, while Figs. Nos. 10 and 11 show miscellaneous fractures, some of which are especially poor.

Graphs are plotted for one specimen under each type of fish plate arrangement, for each method of welding. The results of the tests indicate that the number of weld seams of good appearance run about as follows:

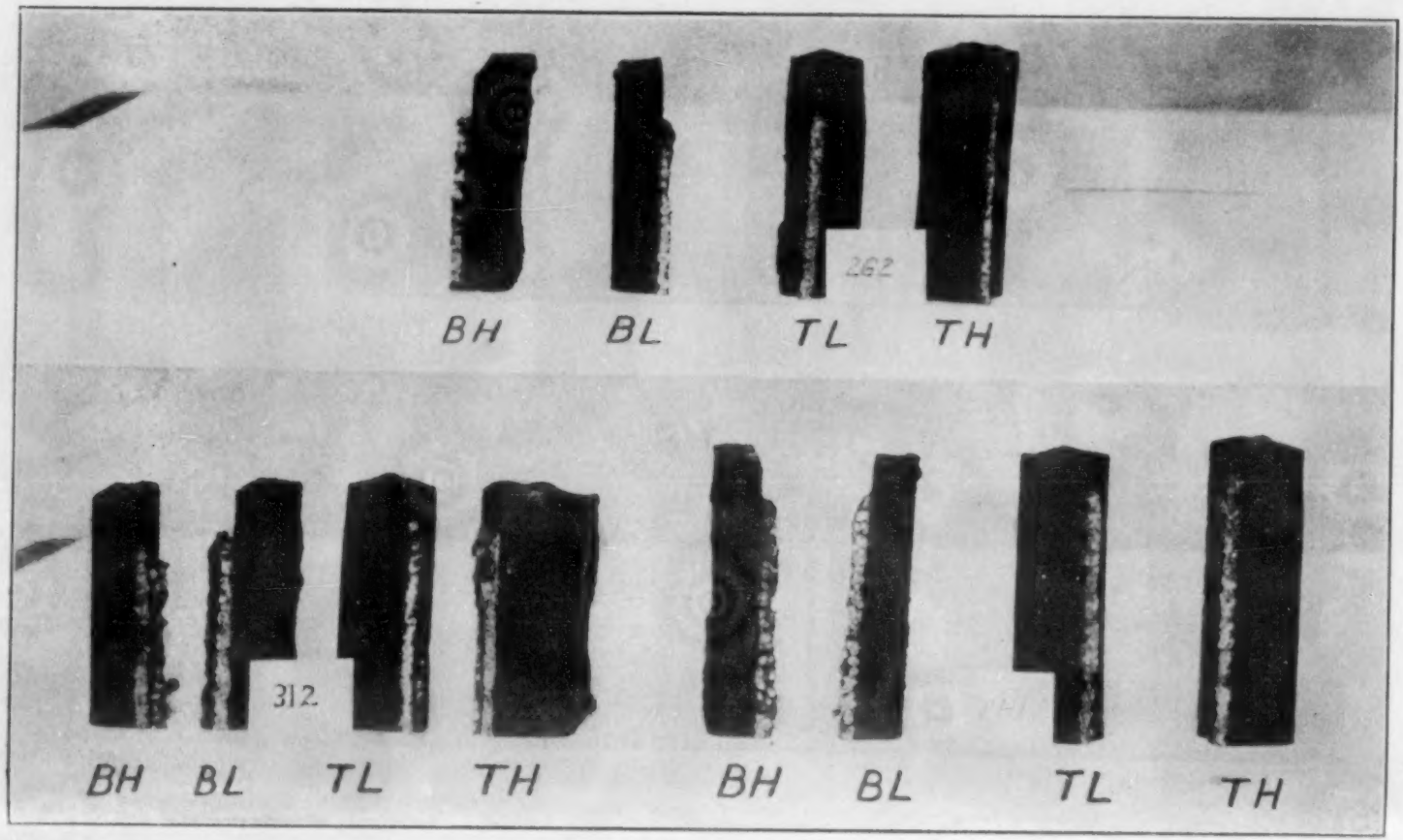
Hand Feed	Group A	36	Rod in Place	Group D	34	Metallic Electrode	Group G	12
	Group B	33		Group E	16		Group H	16
	Group C	42		Group F	39		Group I	17



Figs. 6 and 7. Showing typical fractures

Fig. 4. Showing types of rail plate arrangements

Fig. 5. Showing typical fractures



Figs. 8 and 9. Showing typical fractures

Figs. 8 and 9. Showing typical fractures

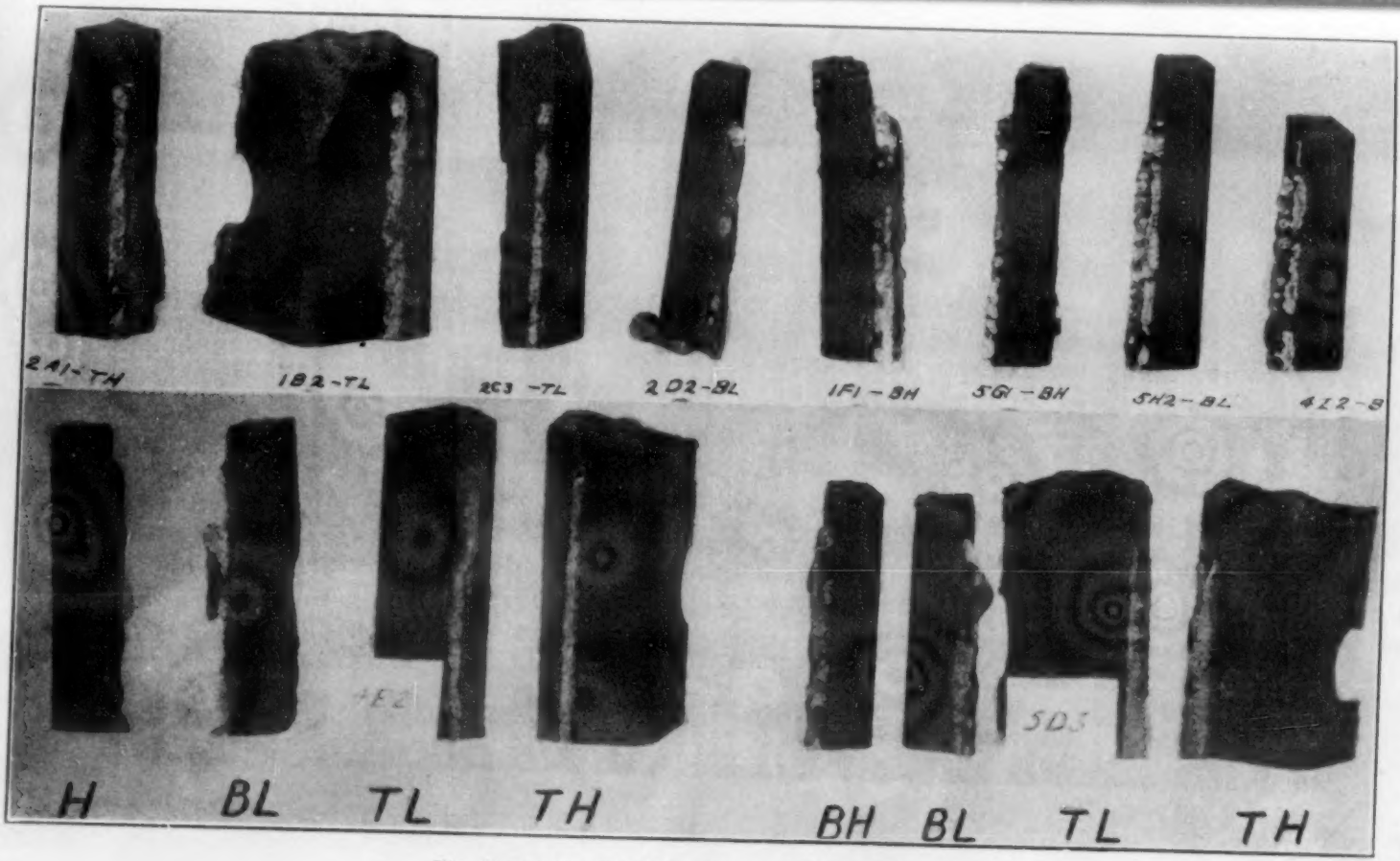


Fig. 10 and 11. Showing some especially poor factures

TABULATED RESULTS
for
Types 1, 2 & 3 - Method "A" Welding

Specimen	Location of seam	Area sq.in.	Proportional limit lbs.	Proportional limit #/sq.in.	Maximum load lbs.	Maximum load #/sq.in.	Appearance of fracture	Load at sign of first crack	Gross Length of weld
	Top-Lip	1.009	30000	29750	39000	38700	Good	39000	5.15
	Top-Head	.968	30000	31000	38000	39250	Poor	35000	5.60
1A1s	Base-Lip	1.532	30000	19450	44700	29000	Good	40000	5.30
	Base-Head	1.265	30000	23800	37000	29200	Poor	30000	5.35
	Top-Lip	1.440	35000	24300	48500	33600	Fair	40000	5.20
	Top-Head	1.084	32500	30000	48500	44700	"	33600	5.55
1A2s	Base-Lip	1.124	30000	26700	41500	36900	Good	32250	5.05
	Base-Head	1.036	30000	29000	41400	40000	"	30000	5.05
	Top-Lip	1.320	30000	22700	45950	34800	"	40900	5.45
	Top-Head	1.338	39000	29200	64800	48500	"	42150	4.40
1A3s	Base-Lip	0.920	25000	27200	36150	39300	Fair	32200	4.60
	Base-Head	1.164	35000	30100	47730	41000	Good	30000	4.75
	Top-Lip	1.182	31000	26200	45400	38400	"	35000	5.30
	Top-Head	.931	25500	27400	34800	37400	Spotted	30000	5.05
2A1s	Base-Lip	1.169	27500	23500	43040	41900	Good	35000	5.15
	Base-Head	1.137	27000	23800	45940	40500	"	40000	5.10
	Top-Lip	1.178	11250	9600	18600	15900	Very Poor	18000	3.90
	Top-Head	.875	21000	24000	28500	32600	Fair	27550	4.00
2A2	Base-Lip	1.087	29500	27150	39000	32900	Good	33300	3.70
	Base-Head	.717	20000	27900	22900	31900	Spotted	22650	3.75
	Top-Lip	.811	25000	30800	31800	39200	"	27900	5.00
	Top-Head	.738	20000	27100	23600	32000	"	20000	4.80
2A3	Base-Lip	1.136	34500	30400	42600	37500	Good	40000	4.60
	Base-Head	1.198	32500	27200	44500	37200	"	34550	4.85
	Top-Lip	1.399	31000	22200	47750	34200	"	43600	5.40
	Top-Head	1.496	33000	22000	54300	36200	"	-	5.70
3A1w	Base-Lip	1.029	25000	24300	36600	35600	"	28500	4.90
	Base-Head	1.298	27000	20800	46300	35600	"	37600	4.90
	Top-Lip	1.122	20000	17800	36720	32600	"	25000	4.30
	Top-Head	1.269	20000	15800	29700	23400	"	25000	4.70
3A2w	Base-Lip	1.093	26000	23800	38000	34700	"	30000	4.05
	Base-Head	0.839	24000	28600	32000	38200	"	30000	3.95
	Top-Lip	1.404	30000	21400	51570	36700	"	41900	5.05
	Top-Head	1.428	31500	22100	43050	30200	"	32250	5.10
3A3	Base-Lip	1.048	30500	29100	42530	40600	Fair	38970	4.85
	Base-Head	1.195	26500	22200	46900	39200	Good	30000	5.15
	Top-Lip	1.402	30000	21400	42650	30400	Good	30000	5.50
	Top-Head	1.378	30000	21800	48110	35000	Fair	30000	5.20
4A1	Base-Lip	1.175	25000	21200	34320	29200	"	30000	4.70
	Base-Head	1.060	27000	25400	35900	33900	"	35000	5.30
	Top-Lip	1.579	33000	20900	51580	32700	Good	30000	5.60
	Top-Head	1.775	32000	18000	36650	20600	"	30000	5.00
4A2	Base-Lip	1.056	25000	23600	31380	25600	"	25000	5.20
	Base-Head	1.199	30000	25000	35000	29200	"	30000	4.70
	Top-Lip	1.256	25000	19900	39400	31400	Fair	29460	4.65
	Top-Head	1.123	30000	26700	44840	39900	Good	27000	5.20
4A3	Base-Lip	.995	25000	25100	33300	33400	Fair	28970	5.13
	Base-Head	.656	20000	30500	23950	36500	Poor	21500	5.00
	Top-Lip	1.755	30000	17100	54980	31300	Good	35000	5.85
	Top-Head	1.693	30000	17700	47190	27800	Fair	40000	5.10
5A1	Base-Lip	1.389	26000	20200	48940	35200	Good	40000	5.05
	Base-Head	1.114	25000	22400	38980	35000	Spotted	30000	5.90
	Top-Lip	1.537	35000	22800	51000	33200	Good	33880	5.30
	Top-Head	1.500	32000	21300	45550	30400	"	30000	5.00
5A2	Base-Lip	1.064	24000	23500	37430	35200	Fair	32000	4.95
	Base-Head	1.129	24000	21300	35580	31600	"	27810	4.95
	Top-Lip	1.123	30000	26700	42170	37400	Good	32750	4.62
	Top-Head	1.545	31000	20000	40350	26100	Fair	33500	5.15
5A3	Base-Lip	1.100	30000	27300	40600	36900	"	34040	5.00
	Base-Head	1.235	31000	25100	43500	35200	Good	33840	4.75

TABULATED RESULTS
for
Types 1, 2 & 3 - Method "B" Welding

Specimen	Location of Seam	Area sq. in.	Proportional limit lbs.	Proportional limit #/sq.in.	Maximum load lbs.	Maximum load #/sq.in.	Appearance of fracture	Load at sign of 1st crack	Gross Length of Weld
1B1	Top-Lip	1.320	35000	26500	49800	37700	Fair	35000	4.55
	Top-Head	1.470	30000	20400	53500	36400	Good	30000	5.05
	Base-Lip	1.274	25000	19600	43800	33900	Fair	30000	4.50
	Base-Head	1.290	25000	19400	42250	32800	"	35000	4.30
1B2	Top-Lip	.343	10000	29300	21250	62000	Spotted		4.35
	Top-Head	1.785	35000	19600	57100	32000	Good	34680	5.10
	Base-Lip	1.257	30000	23900	40000	31800	Fair	15000	4.35
	Base-Head	1.325	20000	15100	22500	17000	Poor		5.00
1B3	Top-Lip	.760	16500	21750	33150	43600	Spotted	39800	4.45
	Top-Head	1.908	37500	19650	69600	36500	Good	40000	5.30
	Base-Lip	1.247	30000	24100	46500	37300	Good	36500	4.30
	Base-Head	1.213	20000	16500	27300	22500	Very Poor	25000	4.85
2B1	Top-Lip	.990	25000	25300	38900	39300	Fair	35400	4.95
	Top-Head	.935	27000	28900	39900	42700	Spotted	24700	5.80
	Base-Lip	1.661			48080	28900	Fair	42150	4.55
	Base-Head	1.160	27000	23300	39400	33950	"	34800	4.55
2B2	Top-Lip	.898	20000	22400	32100	36000	"	29000	4.35
	Top-Head	.660	18500	28000	29250	44300	Good	27800	4.10
	Base-Lip	1.005	27500	27400	37500	37400	Fair	32200	3.35
	Base-Head	.998	20000	20000	34000	34000	Poor	24500	3.90
2B3	Top-Lip	1.024	28500	27800	40800	39800	Good	28180	4.00
	Top-Head	1.089	24500	24000	36770	36000	Fair	28000	5.10
	Base-Lip	1.178	25000	21300	39240	33500	Good	27440	5.05
	Base-Head	1.380	31500	22800	50700	36800	Good	35000	4.80
3B1	Top-Lip	.975	25000	25700	34800	35800	"	22700	3.80
	Top-Head	1.388	29500	21200	49600	35800	"	37700	5.40
	Base-Lip	1.193	31000	26000	43800	36700	"	37100	4.50
	Base-Head	.977	20000	20400	39200	40100	"	29400	4.55
3B2	Top-Lip	.958	25000	26000	31000	32400	"	24300	3.55
	Top-Head	1.335	24500	18350	33360	25000	Fair	22500	3.75
	Base-Lip	1.070	30000	28000	41400	38700	Good	32570	4.10
	Base-Head	1.090	25000	22900	35300	32400	"	30000	3.55
3B3	Top-Lip	1.499	32000	21300	46640	31100	"	33270	5.15
	Top-Head	1.432	33500	23500	48720	34200	"	29540	5.60
	Base-Lip	1.500	32000	21300	46500	31000	"	25000	5.00
	Base-Head	1.625	32000	19700	44800	27500	"	33740	4.85
4B1w	Top-Lip	1.326	29500	22300	44080	33200	Fair	30000	5.10
	Top-Head	1.570	26000	16550	43800	27800	Good	36150	5.00
	Base-Lip	1.139	28000	24600	36650	32200	"	28000	4.95
	Base-Head	1.449	31500	21700	39100	27000	Fair	30000	4.60
4B2w	Top-Lip	1.140	25000	21900	40970	35900	Good	25000	3.80
	Top-Head	.815	22000	27100	28400	34900	Spotted	28000	4.60
	Base-Lip	1.432	23000	16100	28000	19500	Fair	25000	3.50
	Base-Head	.930	20000	21500	27420	29500	Spotted	27300	4.05
4B3w	Top-Lip	1.725	20000	11600	36200	21000	Good	30000	5.00
	Top-Head	1.683	39500	23500	53250	31600	"	45000	5.10
	Base-Lip	1.195	28500	23900	42400	35500	Spotted	30000	5.40
	Base-Head	1.556	34500	22200	55400	35600	Good	45000	5.10
5B1w	Top-Lip	2.064	37500	18150	69550	33700	Good	49600	5.40
	Top-Head	1.300	38500	29600	49050	37700	"	25000	5.00
	Base-Lip	1.075	31000	28800	36400	33800	"	36000	5.00
	Base-Head	1.296	30000	23100	42300	32600	"	34000	4.80
5B2w	Top-Lip	1.733	34500	19900	42590	24600	"	35000	5.25
	Top-Head	1.766	27000	15300	39470	22400	"	30000	5.55
	Base-Lip	1.678	32500	19400	42290	25200	Spotted	35000	5.00
	Base-Head	.923	22500	24400	31950	34600	Fair	30000	4.50
5B3w	Top-Lip	1.313	26000	19800	44050	33600	Good	30000	5.25
	Top-Head	1.515	25000	16500	35090	21700	"		4.75
	Base-Lip	.907	34500	38000	45540	50200	Spotted	30000	5.25
	Base-Head	1.808	30000	16600	40170	22200	Fair		4.40

TABULATED RESULTS
for
Types 1, 2 & 3 - Method "C" Welding

Specimen	Location of seam	Area sq.in.	Proportional limit lbs.	Proportional limit #/sq.in.	Maximum load lbs.	Maximum load #/sq.in.	Appearance of fracture	Load at sign of 1st crack	Gross Length of Weld
	Top-Lip	0.290	5000	17200	13000	4480	Spotted	-	4.60
	Top-Head	2.054	40000	19400	59220	28800	Good	38300	5.20
1C1s	Base-Lip	1.288	30000	23300	48650	37800	Good	42900	4.60
	Base-Head	1.584	34000	21400	52500	33200	Fair	45550	4.80
	Top-Lip	1.151	31000	26900	46370	40200	Good	35000	4.90
	Top-Head	1.641	37000	22600	54730	33400	"	45000	5.70
1C2	Base-Lip	1.619	30000	18550	56230	34800	"	35000	4.95
	Base-Head	1.793	40000	22300	57740	32200	"	38000	5.25
	Top-Lip	1.313	30000	22800	46910	35700	Good	30000	4.45
	Top-Head	1.824	45000	24600	66300	36300	"	35000	5.70
1C3s	Base-Lip	1.394	30000	21500	45000	32200	"	25000	4.10
	Base-Head	1.858	30000	16200	70680	38200	"	45000	5.05
	Top-Lip	0.285	31500	-	38190		Spotted	35000	4.20
	Top-Head	1.409	50000	36500	68140	48400	Good	65000	5.00
2C1	Base-Lip	1.357	33000	24300	43790	32200	"	40000	4.00
	Base-Head	1.426	35000	24600	54150	38000	"	40000	4.90
	Top-Lip	1.156	25000	21600	40070	34600	Fair	30000	3.70
	TopeHead	1.411	20000	14150	36790	26000	Good	30000	4.55
2C2s	Base-Lip	1.420	20000	14100	33250	23400	Fair	27350	3.55
	Base-Head	1.462	32500	22200	48020	32800	Good	41570	4.25
	Top-Lip	0.784	35000	44600	43950	56100	Spotted	43900	5.05
	Top-Head	1.635	30000	18350	51400	31400	Good	46580	5.45
2C3s	Base-Lip	1.394	30000	21500	43750	31400	"	17900	4.25
	Base-Head	1.586	40000	25200	51900	32800	"	28850	5.05
	Top-Lip	1.540	30000	19500	52450	34000	"	43130	4.40
	Top-Head	1.998	30000	15000	45000	22500	"	43300	5.30
3C1s	Base-Lip	1.364	25000	19800	44200	34900	"	33000	4.30
	Base-Head	1.960	34000	17350	60940	31100	"	47020	4.90
	Top-Lip	1.331	27500	20600	46740	35100	"	35000	4.35
	Top-Head	1.160	30000	25800	41470	35700	Fair	34370	4.00
2C2w	Base-Lip	1.281	30000	23400	47740	37200	Good	38560	4.20
	Base-Head	1.132	25000	22100	41400	36600	"	29500	3.30
	Top-Lip	1.803	39000	21600	57400	31800	Good	38400	5.15
	Top-Head	1.610	30000	18650	48430	30100	"	38310	4.60
3C3w	Base-Lip	1.586	25000	15750	60850	38400	"	50000	4.90
	Base-Head	1.401	34000	22800	54700	39000	"	37750	4.75
	Top-Lip	1.911	36500	19100	70000	36600	Good	48000	5.25
	Top-Head	1.606	35000	21800	56950	35400	Fair	48100	5.05
4C1w	Base-Lip	1.606	36500	22700	50720	31600	Good	42070	5.50
	Base-Head	1.540	30000	19500	46900	30400	"	37200	4.40
	Top-Lip	1.364	22500	16500	36500	26700	Fair	34000	4.40
	Top-Head	1.426	24000	16800	44650	31300	"	40000	4.60
4C2s	Base-Lip	1.153	27000	23400	34000	29400	"	30000	4.15
	Base-Head	1.535	35000	22800	54100	35200	"	50000	4.45
	Top-Lip	1.859	30000	16150	50120	27000	Good	42140	4.70
	Top-Head	1.310	28000	21400	47770	36400	Fair	39210	4.75
4C3s	Base-Lip	1.581	30000	18950	53260	33700	Good	40000	4.25
	Base-Head	1.589	36000	22500	52520	33100	"	40000	4.60
	Top-Lip	1.811	36500	20000	60000	33000	"	40000	5.20
	Top-Head	0.345	15000	43500	20000	58000	Spotted	-	5.75
5C1w	Base-Lip	1.564	34000	21700	53900	34400	Fair	51700	5.30
	Base-Head	1.504	30000	19950	48400	32200	"	-	4.80
	Top-Lip	1.743	36000	20600	63600	36500	Good	44000	5.05
	Top-Head	1.565	40000	25600	61750	39500	"	47900	4.60
5C2w	Base-Lip	1.526	34000	22200	58900	38100	"	48800	4.80
	Base-Head	1.362	32000	24200	48000	35200	"	35000	4.30
	Top-Lip	1.430	40000	28000	50200	35100	"	39450	5.00
	Top-Head	1.072	34000	31700	44940	44700	Spotted	42820	4.75
5C3w	Base-Lip	1.489	35000	23500	58730	39500	Good	42600	4.80
	Base-Head	1.643	33000	20100	56000	34100	Fair	30000	4.50

TABULATED RESULTS
for
Types 1, 2 & 3.- Method "D" Welding

Specimen	Location of seam	Area sq.in.	Proportional limit lbs.	Proportional limit #/sq.in.	Maximum load lbs.	Maximum load #/sq.in.	Appearance of fracture	Load at sign of 1st Crack	Gross Length of Weld
1D1s	Top-Lip	0.789	15000	19050	26300	33400	Fair	25000	4.30
	Top-Head	1.104	22000	19900	34600	31300	Good	30000	4.70
	Base-Lip	0.619	15000	24200	23600	38100	Spotted	23600	4.85
	Base-Head	0.765	24000	31400	26500	34600	"	26500	4.75
1D2s	Top-Lip	1.090	25000	22900	33200	30400	Good	29700	5.20
	Top-Head	0.964	21000	21800	43450	45100	"	28000	5.30
	Base-Lip	0.954	27000	28300	33300	34900	Spotted	25000	5.40
	Base-Head	0.974	23000	23600	36900	37900	Good	25000	5.10
1D3s	Top-Lip	1.014	25000	24600	30600	30200	Good	30000	4.45
	Top-Head	0.765	24000	31400	26050	34000	"	25000	5.10
	Base-Lip	0.956	29000	30300	40730	42600	"	35000	4.90
	Base-Head	1.538	25000	16250	56460	36700	"	45000	5.30
2D1w	Top-Lip	0.468	16000	34300	20600	44200	Spotted	20600	4.90
	Top-Head	0.709	17000	24000	20900	29500	Fair	20000	4.55
	Base-Lip	1.298	30000	23100	44000	33900	Good	40000	5.60
	Base-Head	1.046	30000	28700	39470	37800	"	39470	4.75
2D2s	Top-Lip	0.844	26500	31400	34000	40300	Good	30000	4.85
	Top-Head	0.957	21500	22500	27500	28700	"	25000	4.45
	Base-Lip	0.340	9500	27900	12000	35300	Spotted	-	4.75
	Base-Head	0.460	20000	43500	22200	48300	Fair	22200	4.25
2D3s	Top-Lid	0.730	25000	34200	30000	41100	Spotted	-	4.95
	Top-Head	0.951	20000	21000	35900	37700	Good	33900	5.10
	Base-Lip	0.915	25000	27300	37600	41100	Spotted	30000	5.05
	Base-Head	1.065	25000	23400	42100	39500	"	37750	4.95
3D1s	Top-Lid	0.974	27000	27700	30950	31800	Good	25000	5.10
	Top-Head	0.892	25000	30400	38410	46700	"	25000	5.35
	Base-Lip	1.118	35000	31400	40450	36200	Spotted	40000	5.10
	Base-Head	0.295	6000	20400	8000	27300	"	-	5.10
3D2	Top-Lip	0.600	18000	-	21500	-	Fair	20000	4.40
	Top-Head	0.672	18500	27600	23430	34900	Good	20000	4.00
	Base-Lip	0.968	28000	29000	33430	34600	"	25000	4.25
	Base-Head	0.917	33500	36500	37000	40400	"	38000	4.38
3D3w	Top-Lip	0.976	15000	15400	31600	32400	"	30200	5.65
	Top-Head	1.018	20000	19650	30700	30200	"	21900	5.20
	Base-Lip	1.056	32000	30300	46650	44200	"	36000	5.40
	Base-Head	1.319	25000	20500	42000	34500	Spotted	38500	5.60
4D1s	Top-Lip	0.743	15000	20200	23150	31200	Fair	20000	4.95
	Top-Head	0.932	20000	21400	33000	35400	Good	20000	4.90
	Base-Lip	1.089	30000	27600	35300	32400	"	35000	5.20
	Base-Head	0.968	25000	25800	34770	35900	"	30000	5.20
4D2s	Top-Lip	0.765	17000	22200	26760	34900	Fair	25000	5.60
	Top-Head	0.555	14000	25200	24900	44800	"	24900	4.00
	Base-Lip	1.048	15000	14300	33760	32200	Good	30000	4.10
	Base-Head	0.939	20000	21300	37900	40400	"	30000	3.95
4D3s	Top-Lip	1.050	20000	19050	29900	28500	"	25500	5.00
	Top-Head	0.645	15000	22200	21600	33400	Fair	-	4.90
	Base-Lip	0.977	28000	28600	37300	38200	Good	-	5.00
	Base-Head	1.110	26000	23400	47850	43100	Fair	-	5.15
5D1w	Top-Lip	1.091	25000	22900	36650	33600	Good	30000	4.85
	Top-Head	1.113	22000	19800	28670	25800	"	25000	4.45
	Base-Lip	1.027	29000	28200	40000	38900	"	35000	5.25
	Base-Head	.868	18000	20700	22100	25400	Fair	20000	4.55
5D2w	Top-Lip	1.040	27000	26000	33050	31700	Good	30000	5.20
	Top-Head	1.195	26000	21800	35700	29800	"	30000	5.60
	Base-Lip	0.802	25000	31200	30650	38200	Fair	30000	5.20
	Base-Head	0.900	20000	22200	27150	30200	Good	25000	5.00
5D3w	Top-Lip	1.010	26000	25800	39650	39300	Fair	33750	4.80
	Top-Head	0.982	29000	29500	37800	38500	"	35000	5.40
	Base-Lip	0.986	29000	29400	47000	47600	Spotted	39000	5.20
	Base-Head	0.150	-	-	4000	-	-	-	5.30

TABULATED RESULTS
for
Types 1, 2 & 3 - Method "E" Welding

Specimen	Location of seam	Area sq.in.	Proportional limit lbs.	Proportional limit #/sq.in.	Maximum load lbs.	Maximum load #/sq.in.	Appearance of fracture	Load at sign of 1st Crack	Gross Length of Weld
	Top-Lip	0.905	25000	27600	28000	30900	Fair	27660	5.10
	Top-Head	1.580	35000	22200	52120	33000	Good	40000	5.55
1E1s	Base-Lip	0.787	17000	21600	26880	34200	Spotted	25000	5.00
	Base-Head	0.532	29000	54400	34900	65500	"	34900	5.15
	Top-Lip	1.214	33000	27200	36600	30200	Fair	35000	5.45
	Top-Head	1.321	55000	41600	74000	56000	Good	60000	5.30
1E2s	Base-Lip	0.404	14000	34600	18400	45500	Spotted	17500	5.35
	Base-Head	1.730	40000	23100	59600	34500	Good	45000	5.25
	Top-Lip	0.157	10000	63900	15150	96500	Spotted	14000	5.20
	Top-Head	1.647	45000	27300	58000	35200	Good	50000	5.25
1E3s	Base-Lip	1.417	35000	24700	53480	37700	Spotted	45000	5.45
	Base-Head	1.486	38000	25600	57500	38600	Fair	40000	5.03
	Top-Lip	1.241	29000	23400	39700	32000	Fair	29400	4.60
	Top-Head	1.267	27000	21300	33350	26300	"	33000	5.15
2E1w	Base-Lip	1.309	29000	22200	44800	34300	Spotted	41000	4.95
	Base-Head	1.211	30000	24800	50850	42000	Fair	34600	4.95
	Top-Lip	1.178	21000	17850	31200	26500	Fair	30000	4.60
	Top-Head	1.100	16000	14550	21580	19600	"	20900	4.00
2E2	Base-Lip	0.700	20000	28600	30000	42800	Spotted	28520	4.40
	Base-Head	1.131	30000	26500	35900	31700	"	35000	4.50
	Top-Lip	0.927	16000	17250	27000	29100	Fair	25000	3.90
	Top-Head	1.481	30000	20200	40290	27200	Good	35000	4.85
2E3s	Base-Lip	0.979	25000	25500	35470	36200	Poor	30000	4.35
	Base-Head	1.176	27000	23000	41310	35100	Fair	36700	4.80
	Top-Lip	1.718	25000	14550	38750	22600	Fair	30000	4.70
	Top-Head	1.069	15000	14050	30700	28700	Good	30000	5.00
3E1s	Base-Lip	0.858	25000	29100	27000	31500	Spotted	20000	5.45
	Base-Head	0.722	25000	34600	29000	40200	"	28100	4.70
	Top-Lip	.945	22000	23300	26000	27500	Fair	25000	4.15
	Top-Head	1.223	26000	21200	34100	27800	"	29200	4.00
3E2w	Base-Lip	0.840	16000	19050	22200	26400	Spotted	22200	4.30
	Base-Head	1.523	29000	19000	47070	30800	Fair	35000	4.35
	Top-Lip	1.063	27000	25400	40750	38300	Fair	33400	4.85
	Top-Head	1.938	28000	14450	38600	19900	"	35000	5.10
3E3w	Base-Lip	1.865	32000	17150	62450	33400	Good	37450	4.85
	Base-Head	1.712	30000	17500	59000	34400	Fair	42700	5.45
	Top-Lip	1.410	29000	20600	41750	29600	Good	32900	4.88
	Top-Head	1.828	27000	14750	49100	26900	"	39000	5.15
4E1w	Base-Lip	1.374	28000	20400	38300	27700	Fair	33800	5.15
	Base-Head	1.132	30000	26500	40000	35400	"	35000	5.20
	Top-Lip	1.209	23000	19050	27300	22600	Good	15000	3.95
	Top-Head	1.174	5000	4200	8200	7000	"	-	4.15
4E2s	Base-Lip	0.758	25000	33000	32300	42600	Spotted	-	4.20
	Base-Head	1.291	30000	23200	36000	27900	"	30000	4.40
	Top-Lip	1.372	26000	18900	40980	29800	Good	29520	5.30
	Top-Head	2.010	15000	7500	54210	26900	"	35000	5.40
4E3s	Base-Lip	0.346	9000	26000	10600	30600	Poor	10600	4.85
	Base-Head	1.240	33000	26600	44430	35800	Spotted	35000	5.35
	Top-Lip	1.417	26500	18700	40400	28400	Good	25000	4.50
	Top-Head	1.201	27000	22500	42700	35600	"	35000	5.55
5E1	Base-Lip	0.522	18000	34500	24800	47500	Spotted	-	5.40
	Base-Head	0.730	16500	22600	28700	39200	Fair	25000	5.35
	Top-Lip	1.176	24000	20400	40710	34700	Fair	30000	4.80
	Top-Head	1.023	20000	19550	27490	26800	"	25000	4.65
5E2w	Base-Lip	1.449	31000	21400	57000	39400	Good	40000	5.20
	Base-Head	0.283	10000	35300	13000	45900	Spotted	10000	4.25
	Top-Lip	1.466	38000	25900	56080	38300	Spotted	46800	5.70
	Top-Head	1.057	27000	25600	34850	33000	Fair	26150	5.05
5E3w	Base-Lip	0.975	30000	30800	39450	40400	"	30000	4.65
	Base-Head	0.527	21500	40800	28000	53100	"	27400	5.25

TABULATED RESULTS
for
Types 1, 2 & 3 - Method of Welding

Specimen	Location of seam	Area sq.in.	Proportional limit lbs.	Proportional limit #/sq.in.	Maximum load lbs.	Maximum load #/sq.in.	Appearance of fracture	Load at sign of 1st crack	Gross Length of weld
	Top-Lip	0.975	35000	35900	37880	38900	Fair	35000	4.77
	Top-Head	2.240	35000	15650	51600	23100	Good	40000	5.85
1F1s	Base-Lip	1.811	32000	17650	62200	34300	"	40000	5.25
	Base-Head	1.063	32000	29500	40700	37600	Spotted	40000	5.15
	Top-Lip	1.150	32000	27800	41300	35900	Good	40000	4.85
	Top-Head	2.150	40000	18600	65830	30600	"	50000	5.75
1F2s	Base-Lip	1.890	35000	18500	57720	30600	"	45000	5.50
	Base-Head	1.352	25000	18450	53930	39800	"	35000	5.35
	Top-Lip	2.003	39000	19450	50000	24900	"	50000	5.55
	Top-Head	2.129	37000	17400	59550	28000	"	55000	5.92
1F3s	Base-Lip	1.574	30000	19050	65900	41800	"	55000	5.95
	Base-Head	1.583	38000	24000	54800	34600	Fair	40000	5.90
	Top-Lip	1.758	33000	18750	51500	29300	Good	50000	4.45
	Top-Head	1.176	33000	28100	41800	35600	"	40000	4.80
2F1w	Base-Lip	1.339	35000	26200	51000	38100	"	45000	4.25
	Base-Head	0.746	24000	32200	27500	36800	Spotted	27500	4.95
	Top-Lip	0.657	17500	26600	26550	40400	Good	26550	3.75
	Top-Head	1.125	28000	24900	36800	32700	"	35000	3.90
2F2w	Base-Lip	0.983	25000	25400	36400	37000	Spotted	-	3.50
	Base-Head	1.458	28000	19200	48850	33500	Good	45000	4.35
	Top-Lip	1.552	33000	21200	53800	34600	Good	25000	5.40
	Top-Head	1.423	36000	25300	41700	29300	"	30000	5.05
2F3s	Base-Lip	0.726	19000	26200	27000	37200	Fair	-	4.95
	Base-Head	0.750	15500	20700	24800	33100	"	20000	4.85
	Top-Lip	1.926	23000	11950	52500	27300	Good	45000	5.50
	Top-Head	0.435	29000	66600	39400	90500	Spotted	35000	5.80
3F1s	Base-Lip	1.101	15000	13600	19400	17600	"	-	5.30
	Base-Head	1.279	20000	15700	40950	32000	"	30000	5.20
	Top-Lip	1.802	22000	12200	34300	19050	Good	30000	4.30
	Top-Head	1.338	22000	16450	28100	21000	"	25000	4.60
3F2s	Base-Lip	0.678	27000	39800	31750	46700	Spotted	-	4.80
	Base-Head	0.401	5000	12500	7000	17500	Poor	-	4.40
	Top-Lip	1.604	34000	21200	52400	32600	Good	45000	5.20
	Top-Head	0.923	10000	10800	14800	16050	Fair	10000	4.75
3F3w	Base-Lip	2.038	36000	17650	74050	36300	Good	40000	5.15
	Base-Head	1.374	30000	21800	50000	36400	Spotted	30000	4.90
	Top-Lip	1.773	27000	15200	48600	27400	Good	35000	5.00
	Top-Head	2.146	26000	12100	44760	20800	"	40000	5.25
4F1w	Base-Lip	1.780	36000	20200	60700	34200	"	-	5.15
	Base-Head	1.757	30000	17100	55600	31700	"	40000	5.30
	Top-Lip	1.656	21000	12700	42200	25500	"	30000	4.25
	Top-Head	1.369	21000	15350	32600	23800	"	25000	4.45
4F2w	Base-Lip	1.234	34000	27500	53400	43200	"	50000	4.15
	Base-Head	0.805	20000	24809	31800	39500	Fair	25000	4.20
	Top-Lip	1.685	29500	17500	45750	27200	Good	35000	5.25
	Top-Head	1.690	36000	21300	41800	24700	"	-	5.55
4F3s	Base-Lip	1.653	46000	27800	60000	36300	Spotted	60000	5.90
	Base-Head	-	-	-	-	-	-	-	--
	Top-Lip	1.805	35000	19400	58800	32600	Good	45000	5.15
	Top-Head	1.628	25000	15250	40550	24800	"	35000	5.30
5F1w	Base-Lip	1.587	31000	19550	68000	29800	"	45000	5.15
	Base-Head	1.902	38000	19950	64300	33800	"	55000	5.25
	Top-Lip	1.443	38500	26700	57900	40000	"	45000	4.65
	Top-Head	1.685	13000	7700	42950	25400	"	35000	5.25
5F2w	Base-Lip	1.160	29000	25000	43300	37400	Spotted	40000	5.75
	Base-Head	1.458	36000	24700	50450	34600	"	40000	5.10
	Top-Lip	1.113	21000	18900	38150	34400	Fair	30000	4.00
	Top-Head	1.845	35000	17900	42500	23100	Good	40000	5.20
5F3w	Base-Lip	1.310	33000	25200	59650	45600	"	35000	4.85
	Base-Head	1.000	27000	27000	35000	35000	Spotted	25000	4.75

TABULATED RESULTS
for
Types 1, 2 & 3 - Method "G" Welding

Specimen	Location of seam	Area sq.in.	Proportional limit lbs.	Proportional limit #/sq.in.	Maximum load lbs.	Maximum load #/sq.in.	Appearance of fracture	Load at sign of 1st Crack	Gross Length of Weld
	Top-Lip	0.642	25000	39700	32500	38600	Poor	30000	4.46
	Top-Head	0.800	35000	43700	47700	59700	Spotted	35000	5.30
1G1w	Base-Lip	0.975	25000	25600	39900	40900	Good	27100	4.66
	Base-Head	0.843	25000	29600	33900	40200	Spotted	30000	4.85
	Top-Lip	1.152	46000	39950	52400	45500	Good	50000	5.35
	Top-Head	0.640	29000	45300	36900	57600	Poor	35000	5.80
1G2w	Base-Lip	1.185	34000	28700	49500	41700	Good	45000	5.17
	Base-Head	0.766	32500	42400	37500	48900	Spotted	30000	5.30
	Top-Lip	1.350	31000	23000	54850	40600	Good	40000	5.30
	Top-Head	1.014	36500	36000	49700	49000	"	45000	5.80
1G3w	Base-Lip	1.147	40000	34900	50000	43600	Fair	45000	5.20
	Base-Head	0.693	26000	40400	33000	47600	Spotted	30000	4.80
	Top-Lip	0.917	37500	40800	45000	49000	Fair	45000	5.80
	Top-Head	0.555	20000	36000	31790	57300	Poor	31790	5.55
2G1s	Base-Lip	0.903	24000	26600	39360	43600	Spotted	35000	5.35
	Base-Head	0.618	26500	42800	33670	54500	"	33670	4.95
	Top-Lip	0.966	25000	25900	41900	43400	Good	41000	4.60
	Top-Head	0.608	22500	37000	31450	51700	"	30000	4.50
2G2s	Base-Lip	0.496	18500	37400	22800	46000	"	-	3.75
	Base-Head	0.448	18500	41300	22900	51000	Spotted	22000	3.70
	Top-Lip	1.008	44000	43600	47150	46800	Spotted	45000	5.25
	Top-Head	1.008	42000	41800	56750	56600	Good	50000	5.80
2G3w	Base-Lip	0.745	28500	38200	34800	46700	Spotted	34000	4.95
	Base-Head	0.838	29000	34600	39300	46900	"	35000	5.10
	Top-Lip	0.843	26000	30800	38300	45500	Spotted	35000	5.40
	Top-Head	1.042	35000	33600	57500	55900	"	35000	5.60
3G1w	Base-Lip	0.848	30000	35400	33200	39200	"	33100	4.65
	Base-Head	0.625	20000	32000	25500	40800	"	25000	4.65
	Top-Lip	0.655	24000	36600	29900	45600	Spotted	-	4.65
	Top-Head	1.020	29500	28900	42800	42000	"	40000	4.70
3G2w	Base-Lip	0.743	28000	37700	35900	48300	"	35000	4.85
	Base-Head	0.655	28500	43500	30700	46800	"	30000	4.25
	Top-Lip	1.344	39000	29000	59150	44100	Spotted	55000	5.80
	Top-Head	0.973	27000	27700	53850	54700	"	33000	5.60
3G3s	Base-Lip	1.018	26500	26100	42700	42000	"	42000	5.25
	Base-Head	0.675	25000	37200	34000	50500	"	34000	4.90
	Top-Lip	0.646	17000	26300	25600	39600	Spotted	25000	5.25
	Top-Head	1.181	31000	26200	45850	38800	Fair	40000	5.20
4G1s	Base-Lip	0.803	28500	35500	34600	43100	Spotted	34000	4.80
	Base-Head	0.585	28000	47800	34900	59600	"	25000	4.80
	Top-Lip	0.518	15000	28900	17470	33300	Spotted	15000	4.75
	Top-Head	0.545	20000	36700	28780	52800	"	28000	4.60
4G2s	Base-Lip	0.820	21000	25600	38170	46600	Fair	35000	4.10
	Base-Head	0.235	10000	42800	13000	55800	Spotted	-	4.00
	Top-Lip	0.979	29000	29600	46600	47600	Spotted	44700	4.75
	Top-Head	0.648	25000	38600	29600	45700	"	28000	5.55
4G3w	Base-Lip	1.037	32500	31600	42900	41700	"	37000	4.90
	Base-Head	0.718	26500	39700	33900	47200	"	33000	4.75
	Top-Lip	1.556	38000	24400	49720	31900	Good	40000	5.65
	Top-Head	0.955	34500	36800	41800	44700	"	40000	5.45
5G1s	Base-Lip	1.079	34000	32000	44500	38800	Fair	40000	5.10
	Base-Head	0.396	20000	50500	24000	60600	Spotted	20000	5.00
	Top-Lip	0.906	27000	29800	42150	46500	Good	40000	5.30
	Top-Head	0.607	20500	33800	24500	40400	Spotted	24000	5.25
5G2s	Base-Lip	0.903	30000	33200	43100	47700	"	35000	4.95
	Base-Head	0.710	31500	44300	37000	52100	"	36000	4.85
	Top-Lip	0.999	34000	34000	38140	38140	Spotted	35000	5.60
	Top-Head	0.904	30000	33200	41550	45900	Fair	40000	5.70
5G3s	Base-Lip	0.916	33500	36600	35900	39200	"	35000	4.95
	Base-Head	0.600	33500	55800	38650	64400	Spotted	35000	5.20

TABULATED RESULTS
for
Types 1, 2 & 3 - Method "H" Welding

Speci-men	Location of seam	Area sq.in.	Proportional limit lbs.	Proportional limit #/sq.in.	Maximum load lbs.	Maximum load #/sq.in.	Appear-ance of fracture	Load at sign of 1st Crack	Gross Length of Weld
1H1s	Top-Lip	1.178	37500	31800	45750	38800	Spotted	45000	4.60
	Top-Head	0.927	26000	28000	36000	38800	"	35000	5.95
	Base-Lip	0.960	31500	32800	44900	46700	"	35000	4.75
	Base-Head	0.836	38000	45400	41770	49800	"	40000	5.10
1H2s	Top-Lip	1.112	35000	31500	57650	51800	Spotted	55000	4.80
	Top-Head	0.766	37000	48300	48200	62800	"	48000	5.70
	Base-Lip	1.280	32000	25000	47000	36700	"	40000	5.10
	Base-Head	0.671	38500	57400	40800	60700	"	40000	5.00
1H3	Top-Lip	1.015	37000	36400	53720	52900	Spotted	45000	4.55
	Top-Head	1.099	45000	41000	65160	59400	"	60000	5.75
	Base-Lip	0.895	38500	43000	42770	47700	"	35000	4.80
	Base-Head	0.615	28500	46300	34000	55500	"	34000	5.00
2H1w	Top-Lip	1.747	35000	20000	56600	32400	Good	55000	5.60
	Top-Head	1.510	40500	26800	62550	41400	"	-	5.95
	Base-Lip	1.053	30000	28500	51550	48900	Spotted	50000	5.45
	Base-Head	0.751	28500	37900	31800	42300	"	30000	5.30
2H2s	Top-Lip	1.271	34000	27500	46550	36600	Good	45000	4.40
	Top-Head	1.102	35000	31700	45600	41400	"	40000	4.90
	Base-Lip	0.762	28500	37400	30800	40400	Spotted	30000	3.65
	Base-Head	0.627	23500	37400	32350	51500	"	-	4.90
2H3s	Top-Lip	1.618	41000	25400	62000	38300	Spotted	60000	5.70
	Top-Head	1.045	39000	37300	49000	46900	Good	35000	5.35
	Base-Lip	0.546	20000	36600	31100	56800	Spotted	30000	5.00
	Base-Head	0.615	30000	48700	34300	55700	"	30000	4.75
3H1s	Top-Lip	1.059	37000	34900	47200	44600	Spotted	46000	5.90
	Top-Head	1.364	36000	26400	46000	33700	Fair	40000	5.85
	Base-Lip	0.865	32000	37100	43110	49900	Spotted	40000	5.15
	Base-Head	1.266	32000	25300	50000	39500	"	40000	4.90
3H2w	Top-Lip	0.346	16500	47600	23000	66500	Spotted	15000	4.90
	Top-Head	1.247	28500	22800	46800	37600	Good	45000	4.75
	Base-Lip	0.884	27000	30500	42400	48000	Spotted	40000	4.00
	Base-Head	1.000	27500	27500	41900	41900	"	40000	4.45
3H3w	Top-Lip	1.268	41000	32300	60000	47300	Spotted	60000	6.15
	Top-Head	1.480	33500	22600	61450	41500	Good	50000	5.65
	Base-Lip	1.080	30000	27800	52000	48200	Spotted	25000	5.30
	Base-Head	0.755	28000	37100	41200	54500	"	30000	5.40
4H1w	Top-Lip	0.958	38500	40200	44700	46600	Spotted	40000	5.85
	Top-Head	1.698	45000	26500	68280	40200	Good	65000	5.70
	Base-Lip	1.424	31500	22100	57390	40300	Spotted	50000	5.30
	Base-Head	1.310	27500	21000	46600	35600	Good	40000	5.20
4H2s	Top-Lip	0.760	28500	37500	35400	46600	Spotted	33000	4.10
	Top-Head	1.172	30000	25600	47000	40100	Good	45000	4.60
	Base-Lip	0.958	33000	34400	36700	38300	Spotted	36000	4.00
	Base-Head	0.723	33000	45600	35750	49400	"	35000	4.15
4H3s	Top-Lip	1.307	41500	31800	56100	43000	Spotted	55000	5.90
	Top-Head	1.510	37000	24500	60400	40000	Good	60000	5.80
	Base-Lip	1.884	51000	24200	50900	39600	Spotted	45000	5.00
	Base-Head	0.765	35500	43900	36450	47800	"	35000	5.10
5H1w	Top-Lip	1.928	50000	26000	75000	38900	Spotted	60000	5.50
	Top-Head	1.530	36000	23500	57670	37700	Good	50000	5.65
	Base-Lip	1.168	34000	29100	54800	46900	Spotted	50000	5.00
	Base-Head	1.317	28500	21600	52430	39800	"	45000	4.95
5H2w	Top-Lip	2.376	55000	23300	85000	34900	Good	55000	5.55
	Top-Head	1.590	39000	24500	55000	34600	"	55000	5.10
	Base-Lip	1.188	36000	30300	55950	47100	Spotted	55000	5.10
	Base-Head	0.993	32500	32700	47600	48200	"	45000	4.80
5H3w	Top-Lip	2.079	43500	23300	73950	35600	Good	70000	5.70
	Top-Head	1.660	42000	25300	59550	36900	"	55000	4.95
	Base-Lip	1.260	35000	27800	58750	46600	Spotted	55000	5.35
	Base-Head	1.347	41500	30800	54500	40600	"	50000	4.95

TABULATED RESULTS
for
Types 1, 2 & 3 - Method "I" Welding

Specimen	Location of seam	Area sq.in.	Proportional limit lbs.	Proportional limit #/sq.in	Maximum load lbs.	Maximum load #/sq.in.	Appearance of fracture	Load at sign of 1st crack	Gross Length of Weld
1I1s	Top-Lip	1.857	39000	21000	68750	37000	Good	40000	5.05
	Top-Head	0.515	36500	72700	39700	77000	Spotted	-	5.50
	Base-Lip	2.048	34500	16800	69350	33900	Good	35000	5.35
	Base-Head	1.145	36500	31800	58950	51500	Spotted	45000	4.50
1I2s	Top-Lip	1.500	40000	26700	64250	42800	Good	60000	5.00
	Top-Head	1.937	43500	22500	71800	37100	"	70000	5.50
	Base-Lip	1.763	35000	19850	65000	36800	Spotted	55000	4.75
	Base-Head	1.577	45000	28500	70580	44800	"	65000	5.10
1I3s	Top-Lip	1.477	48500	32800	73780	50000	Good	70000	4.85
	Top-Head	1.435	46000	32100	60800	42400	Spotted	50000	5.55
	Base-Lip	1.565	36000	23000	61860	39600	"	40000	4.85
	Base-Head	1.242	40000	32200	64300	51700	"	50000	5.05
2I1w	Top-Lip	1.443	51500	35600	64800	44800	Spotted	55000	5.30
	Top-Head	0.850	42500	50000	44800	52700	Fair	44000	5.35
	Base-Lip	1.221	38500	31500	60450	49500	Good	40000	4.70
	Base-Head	1.143	35000	30600	57750	50500	Spotted	45000	4.75
2I2s	Top-Lip	1.320	40000	30300	58300	44200	Good	55000	4.40
	Top-Head	1.392	43000	30900	57860	41500	Fair	48000	4.80
	Base-Lip	1.428	33000	23100	57190	41000	Spotted	45000	4.00
	Base-Head	0.867	35000	40300	35070	40400	Spotted	34200	4.05
2I3s	Top-Lip	1.216	45000	37000	64100	52700	Spotted	55000	5.65
	Top-Head	1.350	28000	20800	57740	42800	Good	50000	5.40
	Base-Lip	1.239	39000	31500	56730	45800	Spotted	55000	4.90
	Base-Head	1.276	37000	29000	61480	48200	"	50000	4.85
3I1s	Top-Lip	1.355	41000	30000	53910	46800	Spotted	60000	5.20
	Top-Head	1.552	40000	25800	53940	34700	Good	50000	5.40
	Base-Lip	1.479	37000	25000	55620	37600	Spotted	50000	5.10
	Base-Head	1.227	36500	29700	46400	37800	"	-	4.90
3I2w	Top-Lip	0.758	31000	40800	44800	59200	Spotted	40000	4.65
	Top-Head	1.063	37000	34800	42900	41300	Fair	43500	4.45
	Base-Lip	1.093	27500	25100	49120	45000	"	44650	4.10
	Base-Head	0.823	37500	45600	42500	51600	Spotted	40000	3.90
3I3w	Top-Lip	1.202	41500	34500	63270	52600	Spotted	55000	5.40
	Top-Head	1.285	34000	26500	49610	38600	"	40000	5.50
	Base-Lip	0.975	35000	35900	47840	49000	"	45000	5.00
	Base-Head	0.921	26000	28200	42610	46300	"	40000	5.20
4I1w	Top-Lip	0.703	33500	47600	37630	53500	Spotted	35000	5.20
	Top-Head	1.423	47500	33400	51600	36200	Good	45000	5.80
	Base-Lip	1.245	32000	25700	55470	44600	Spotted	55000	5.00
	Base-Head	1.000	28000	28000	48160	48160	Spotted	40000	5.10
4I2s	Top-Lip	0.943	35000	37100	46850	49600	Spotted	45000	4.80
	Top-Head	1.426	35500	24900	54000	37900	Good	50000	4.45
	Base-Lip	0.848	37000	43600	44700	52700	Spotted	40000	3.70
	Base-Head	0.920	37500	40700	40000	43500	"	35000	4.05
4I3s	Top-Lip	1.127	40000	35800	56700	49400	Spotted	60000	5.15
	Top-Head	1.838	46000	25100	71250	38800	Good	60000	5.75
	Base-Lip	1.264	39000	30800	60150	47600	Spotted	60000	5.00
	Base-Head	1.125	36000	32000	55000	48900	"	50000	5.10
5I1w	Top-Lip	1.796	46000	25600	74600	41600	Good	65000	5.20
	Top-Head	1.652	42000	25400	59500	36000	"	50000	5.35
	Base-Lip	1.344	40000	29700	57780	43000	Spotted	50000	4.95
	Base-Head	1.542	36500	23600	60930	39400	"	40000	4.95
5I2w	Top-Lip	2.250	51000	22600	76000	33800	Spotted	60000	5.55
	Top-Head	2.067	47000	22700	67350	32500	Good	60000	5.80
	Base-Lip	1.908	42000	22000	74300	38900	"	55000	4.98
	Base-Head	1.635	40000	24500	64000	39200	Spotted	45000	5.15
5I3w	Top-Lip	1.797	45500	25300	64400	35800	Spotted	50000	5.25
	Top-Head	1.774	44000	24800	61470	34600	Good	50000	5.20
	Base-Lip	1.395	34500	24700	60770	43500	Spotted	50000	4.95
	Base-Head	1.375	35500	25800	60650	44200	"	50000	4.75

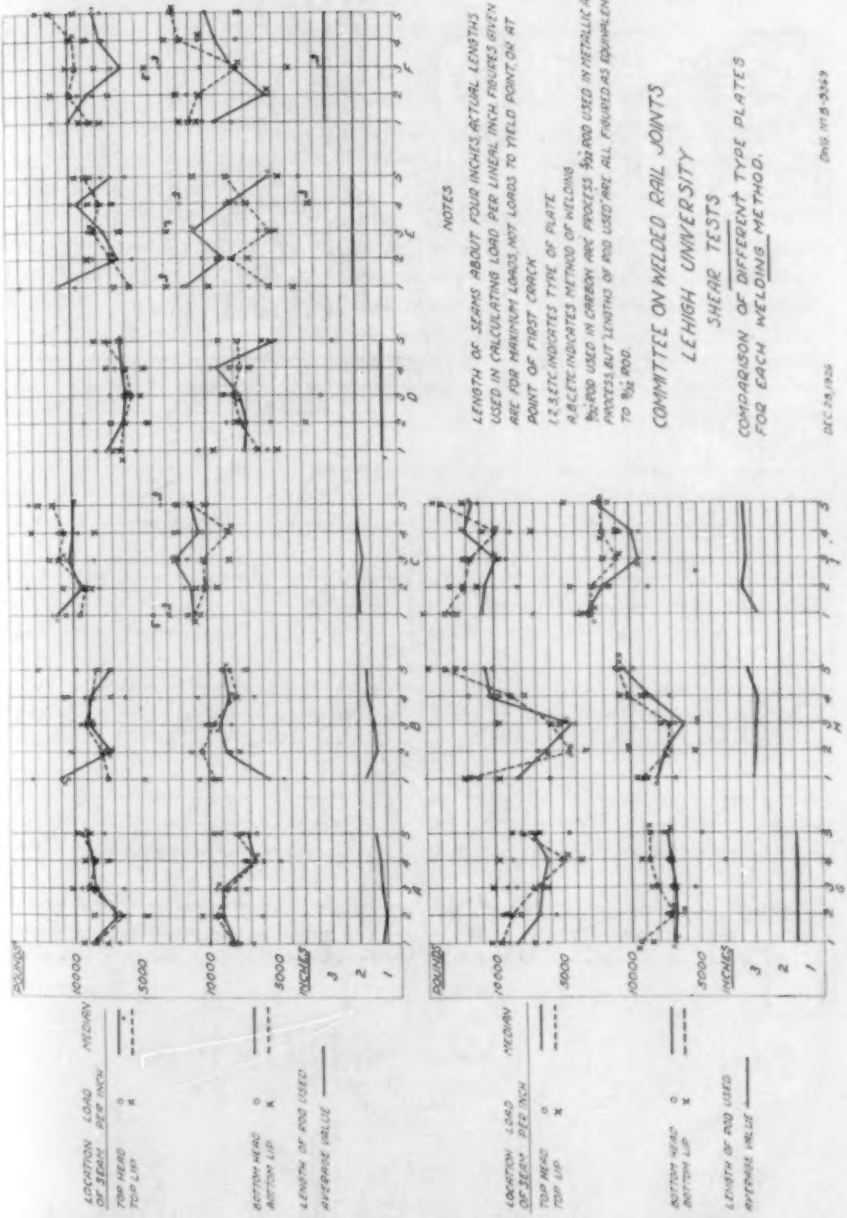

NOTES
LENGTH OF SEAMS ABOUT FOUR INCHES; ACTUAL LENGTHS USED IN CALCULATING LOAD PER LINEAL INCH FIGURES GIVEN ARE FOR MAXIMUM LOADS NOT LOADS TO YIELD POINT OR AT POINT OF FIRST CRACK
1,2,3 ETC. INDICATES TYPE OF PLATE
A,B,C ETC. INDICATES METHOD OF WELDING
5/32 ROD USED IN CARBON ARC PROCESS 5/32 ROD USED IN METALLIC ARC PROCESS, BUT LENGTHS OF ROD USED ARE ALL FIGURED AS EQUIVALENT TO 5/32 ROD.
COMMITTEE ON WELDED RAIL JOINTS
LEHIGH UNIVERSITY
SHEAR TESTS
COMPARISON OF DIFFERENT TYPE PLATES FOR EACH WELDING METHOD.
DEC. 29, 1926
DWG. NO. B-9349
POUNDS
INCHES
LOCATION OF SEAM
LOAD PER INCH
MEDIAN
TOP HEAD
TOP LIP
BOTTOM HEAD
BOTTOM LIP
LENGTH OF ROD USED
AVERAGE VALUE

Fig. 12. Chart to show comparative test results of different types of plates for each welding method. Maximum values per linear inch of seam are given. The median values of the three specimens of each variable are joined by a dotted or full line. Charts on this and following four pages prepared by Third Ave. Railway System

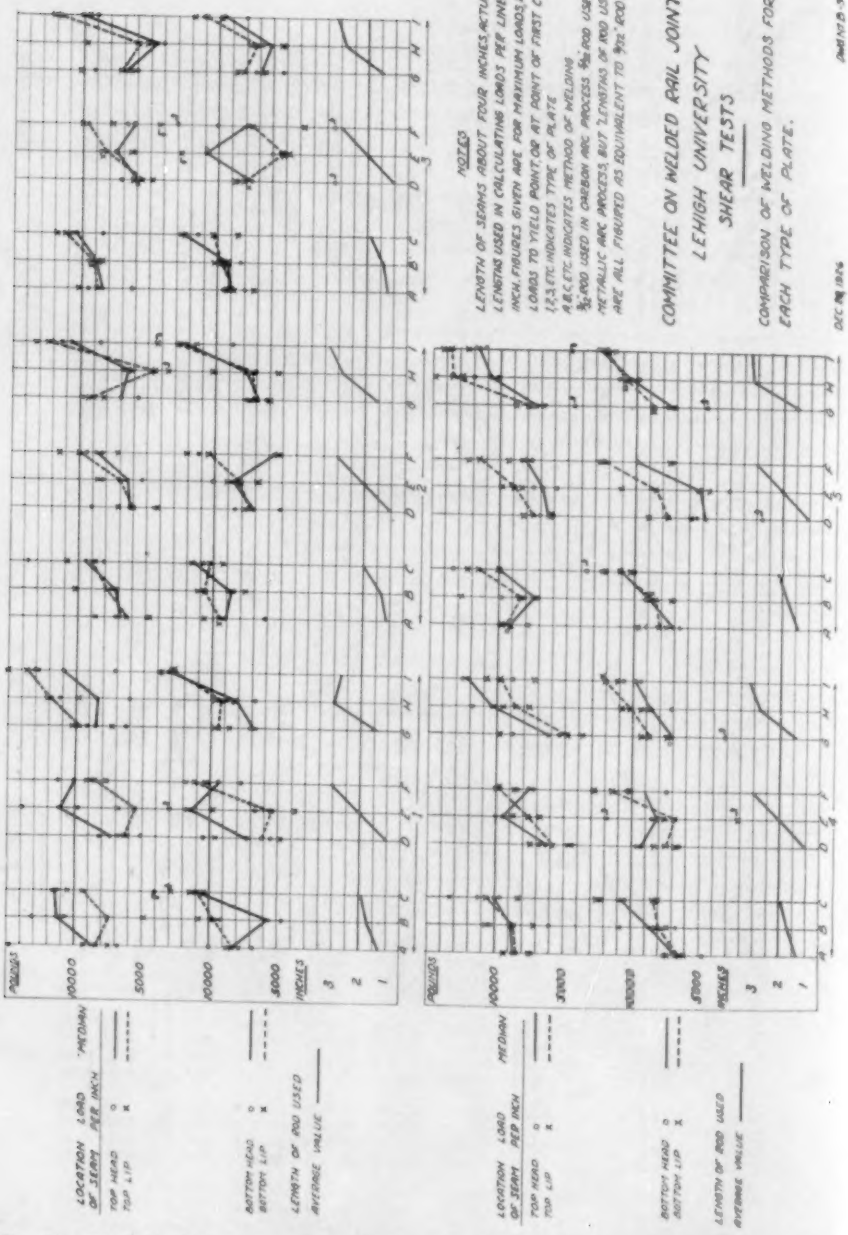

COMMITTEE ON WELDED RAIL JOINTS
LEHIGH UNIVERSITY
SHEAR TESTS
COMPARISON OF WELDING METHODS FOR EACH TYPE OF PLATE.
NOTES
LENGTH OF SEAMS ABOUT FOUR INCHES ACTUAL LENGTHS USED IN CALCULATING LOADS PER LINEAL INCH. FIGURES GIVEN ARE FOR MAXIMUM LOADS NOT LOADS TO YIELD POINT OR AT POINT OF FIRST CRACK.
1,2,3, ETC. INDICATES TYPE OF PLATE
A,B,C, ETC. INDICATES METHOD OF WELDING
5/32 ROD USED IN CARBON ARC PROCESS. 3/16 ROD USED IN METALLIC ARC PROCESS, BUT LENGTHS OF ROD USED ARE ALL FIGURED AS EQUIVALENT TO 3/16 ROD
POUNDS
INCHES
LOCATION OF SEAM
LOAD PER INCH
MEDIAN
TOP HEAD
TOP LIP
BOTTOM HEAD
BOTTOM LIP
LENGTH OF ROD USED
AVERAGE VALUE

Fig. 13. Chart to show comparative test results of different welding methods for each type of plate. Maximum values per linear inch of seam are given. The median values of the three specimens of each variable are joined by a dotted or full line

Analysis of Results of Shear Tests Giving Highest Values

The program of investigational work given in Progress Report No. 3 calls for check tests of full-size specimens in tension and repeated impact of those joint plates and methods of welding selected for further study.

In order to select joint plates and methods of welding which should be used for the remaining investigations of the committee, there were chosen those specimens which gave greater values than 12,000 lb. (except Top Head Seam, where 11,000 was used) shearing strength per linear inch of bead. Each seam is treated separately. The values below have been arranged for convenience to bring out the type of joint plate and method of welding:

TOP HEAD SEAM

Arranged to indicate best plate

1A	2C	4C	5C
1B	2I	4H	5H
1B		4I	5I
1C		4I	5I
1C			5I
1C			
1E			
1E			
1F			
1H			
1I			
1I			

Arranged to indicate best method of welding

A1,
B1, B1
C1, C1, C1, C2, C4, C5
E1, E1
F1,
H1, H4, H5
I1, I1, I2, I4, I4, I5, I5, I5.

It can readily be seen that the joint plates giving the highest shearing strength per linear inch the greatest number of times, were the Shoulder Type and the Rail Joint Company's Type. The methods of welding giving the best results are the carbon arc hand-feed system two layers and the metal arc two layers.

TOP LIP

Arranged to indicate best plate

1H	2I	3I	4C	5C
1I	2I			5B
1I				5F
1I				5H
				5H
				5H
				5I
				5I
				5I

Arranged to indicate best method of welding

B5.
C4, C5.
F5.
H1, H5, H5, H5.
I1, I1, I1, I2, I2, I3, I3, I3, I5, I5 I5.

BOTTOM HEAD

Arranged to indicate best plate.

1C	2I	3I	4C	5C
1I	2I	3I		5F
1I				5I
1I				5I
				5I

Arranged to indicate best method of welding.

C1, C4, C5.
F5.
I1, I1, I1, I2, I2, I3, I3, I5, I5, I5.

BOTTOM LIP

Arranged to indicate best plate.

1I	2F	3C	4C	5C
1I	2I	3E	4F	5F
1I	2I	3F		5F
		3I		5I
				5I

Arranged to indicate best method of welding.

C3, C4, C5.
E3.
F2, F3, F4, F5, F5.
I1, I1, I1, I2, I2, I3, I5, I5.

The above results practically substantiate the conclusions found for the Head Seam that the Shoulder and Rail Joint Company's type of plates gave the highest values the most number of times and the best methods of welding were the carbon arc hand feed system two layers and the metal arc two layers.

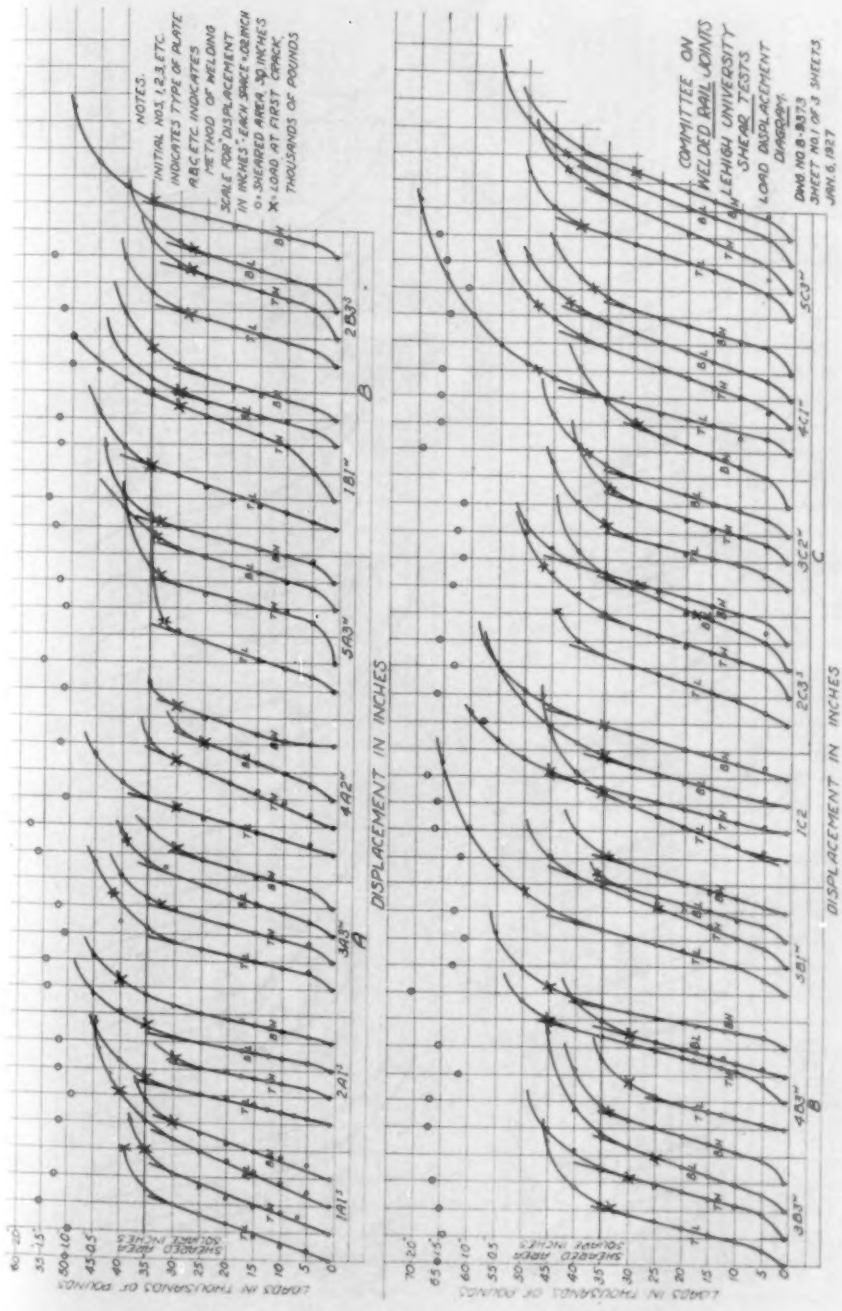

NOTES:
INITIAL NOS. 1,2,3, ETC. INDICATES TYPE OF PLATE
ABC ETC. INDICATES METHOD OF WELDING
SCALE FOR DISPLACEMENT IN INCHES: EACH SPACE = 0.1 INCH
O = SHEARED AREA .10 INCHES
X = LOAD AT FIRST CRACK
THOUSANDS OF POUNDS
COMMITTEE ON WELDED RAIL JOINTS
LEHIGH UNIVERSITY
SHEAR TESTS
LOAD DISPLACEMENT DIAGRAM
DWG NO. B-1373
SHEET NO. 1 OF 3 SHEETS
JAN. 6, 1927
LOADS IN THOUSANDS OF POUNDS
SHEARED AREA SQUARE INCHES
DISPLACEMENT IN INCHES

Fig. 14. Load displacement diagrams of shear test results

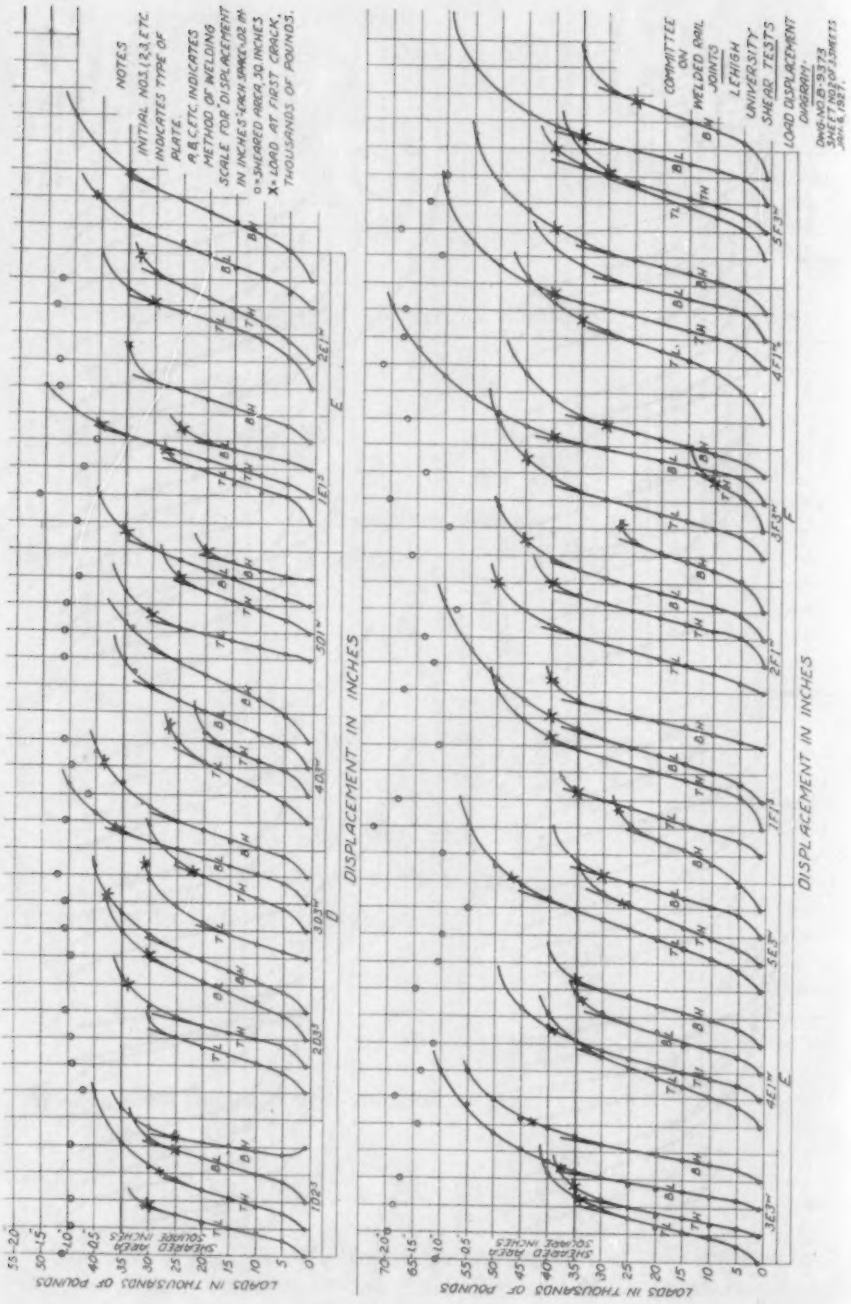

NOTES
INITIAL NOS. (2,3 ETC. INDICATES TYPE OF PLATE
A,B,C ETC. INDICATES METHOD OF WELDING
SCALE FOR DISPLACEMENT IN INCHES
O-SHEARED AREA 30 INCHES
X-LOAD AT FIRST CRACK, THOUSANDS OF POUNDS.
COMMITTEE ON WELDED RAIL JOINTS
LEHIGH UNIVERSITY
SHEAR TESTS
LOAD DISPLACEMENT DIAGRAM
DWG. NO. B-5313
SHT. 1 OF 2 SHEETS
JAN. 6, 1927.
LOADS IN THOUSANDS OF POUNDS
SHEARED AREA SQUARE INCHES
DISPLACEMENT IN INCHES

Fig. 15. Load displacement diagrams of shear test results

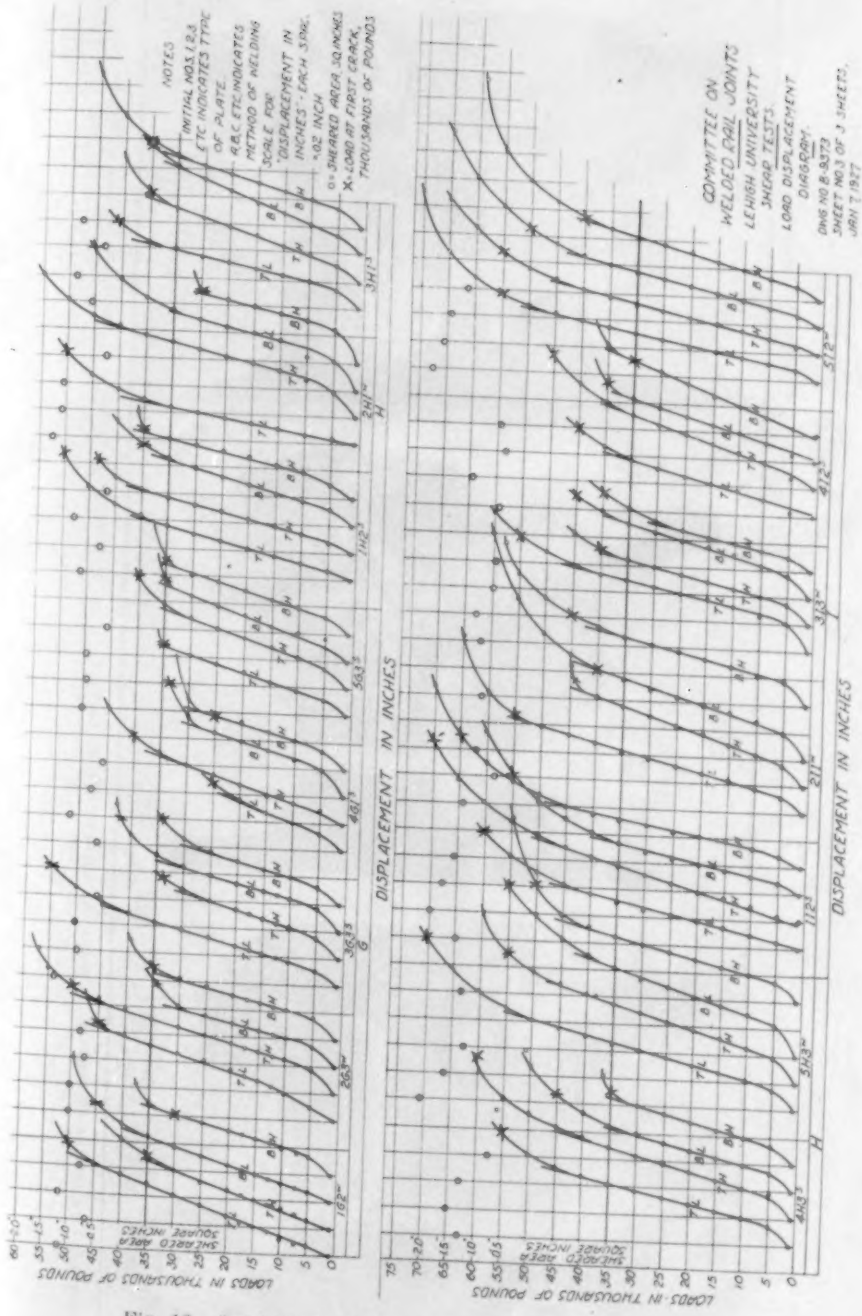

NOTES
INITIAL NOS. I.B.A. ETC INDICATES TYPE OF PLATE.
A.B.C. ETC INDICATES METHOD OF WELDING
SCALE FOR DISPLACEMENT IN INCHES - EACH SQUARE .02 INCH
o - SHEARED AREA 30 INCHES
X - LOAD AT FIRST CRACK, THOUSANDS OF POUNDS
COMMITTEE ON WELDED RAIL JOINTS
LEHIGH UNIVERSITY
SHEAR TESTS
LOAD DISPLACEMENT DIAGRAM.
DNG NO B-8373
SHEET NO 3 OF 3 SHEETS.
JAN 7 1927
LOADS IN THOUSANDS OF POUNDS
SHEARED AREA SQUARE INCHES
DISPLACEMENT IN INCHES

Fig. 16. Load displacement diagrams of shear test, results

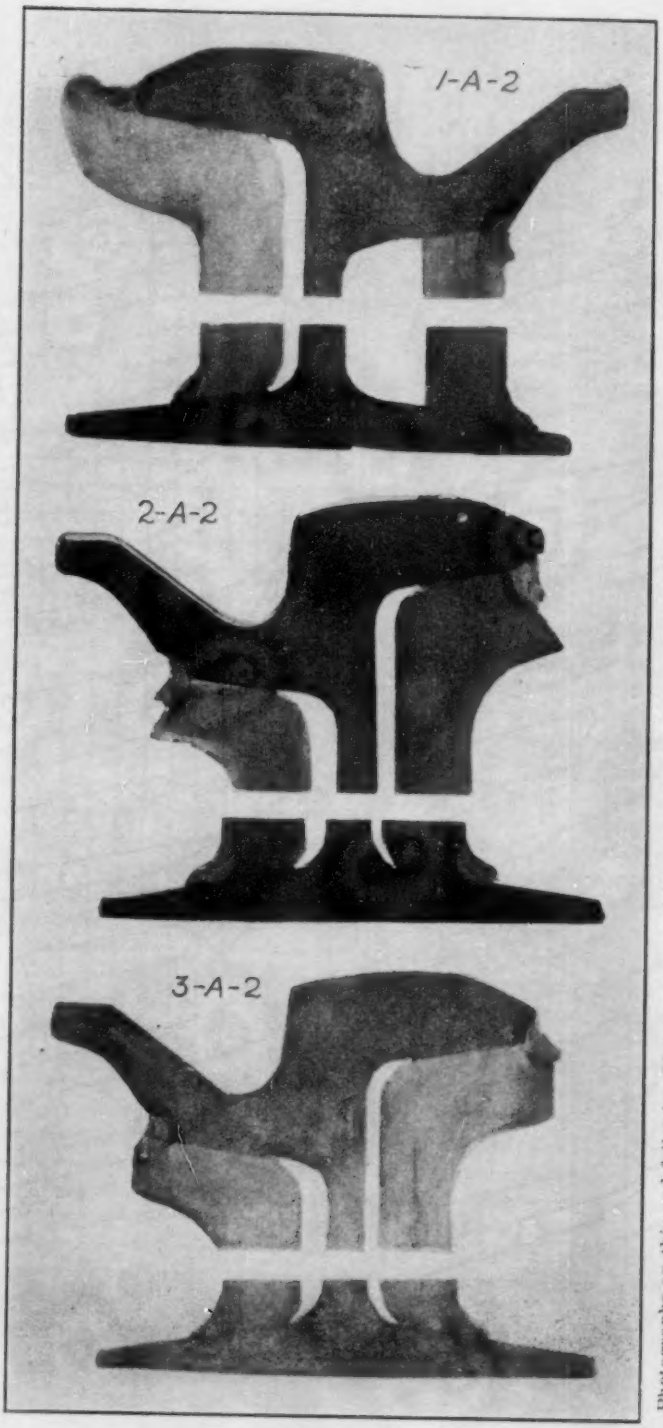


Fig. 17

Photographs on this and following 15 pages prepared by Mr. S. Epstein of the Metallurgical Division of the U. S. Bureau of Standards

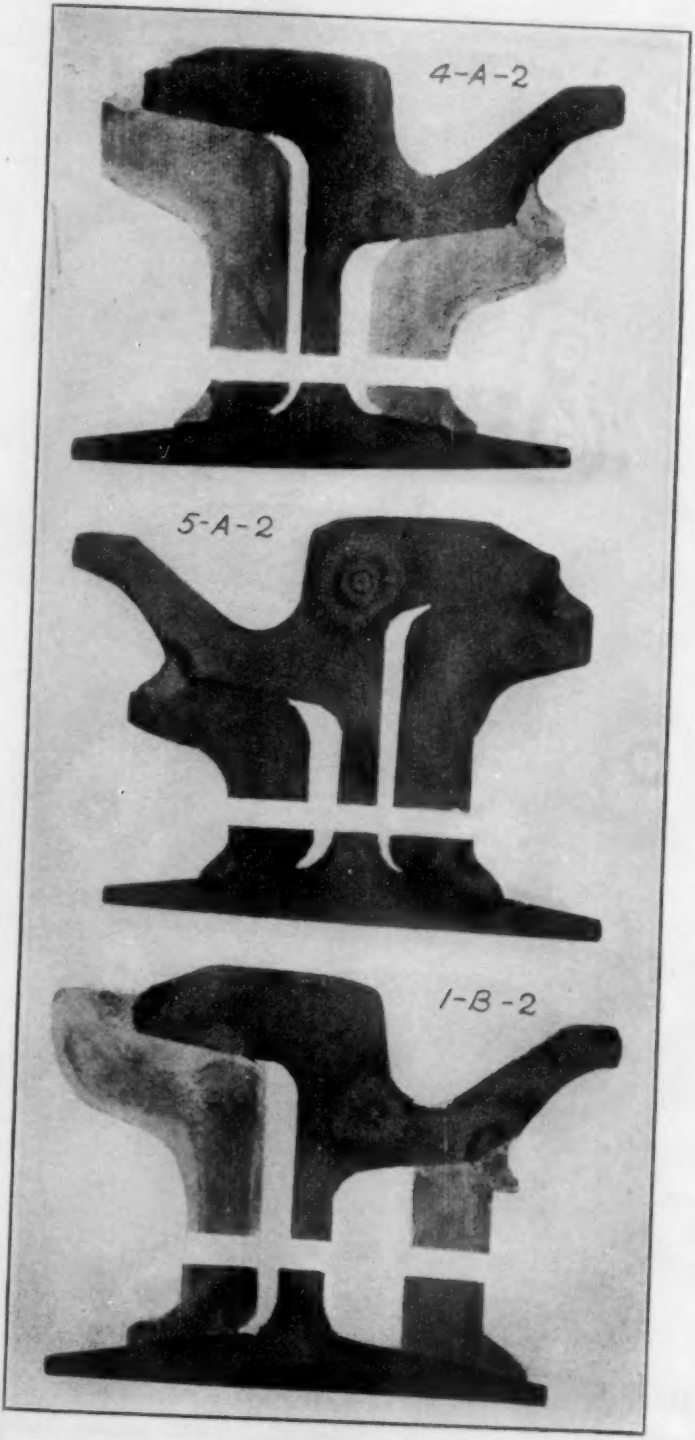


Fig. 18

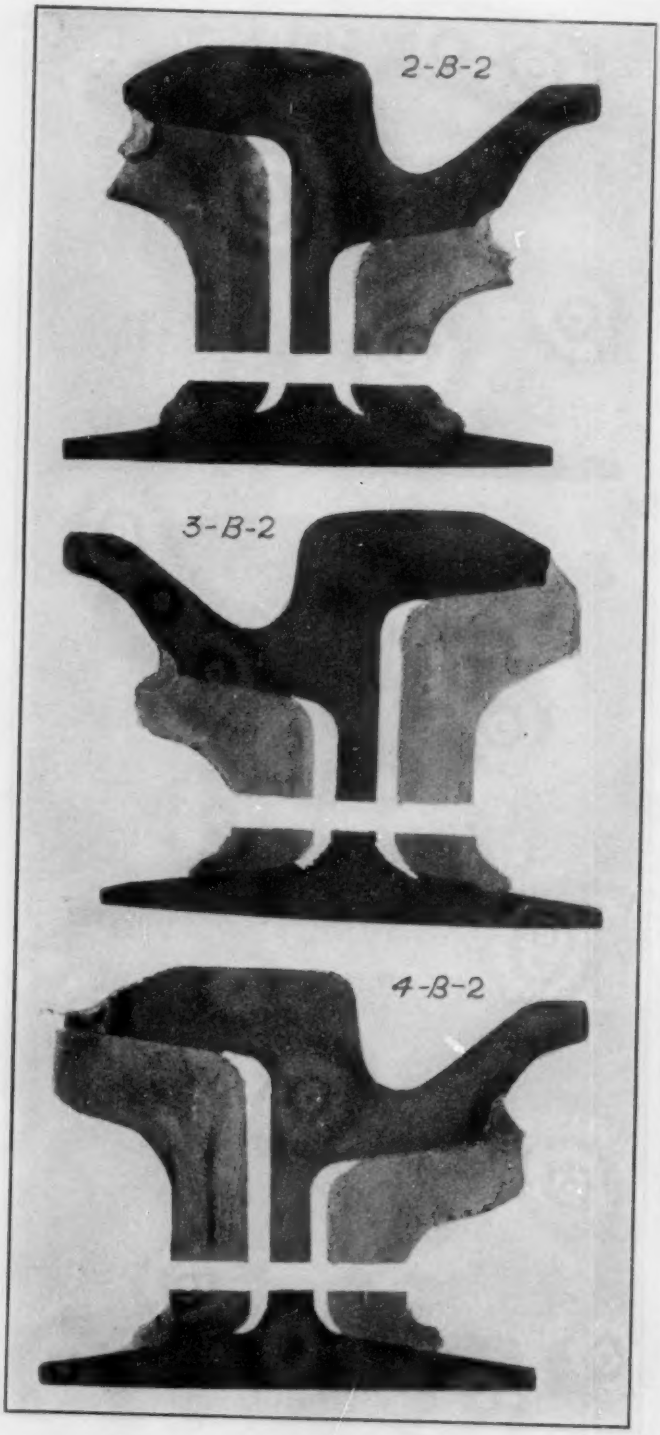


Fig. 19

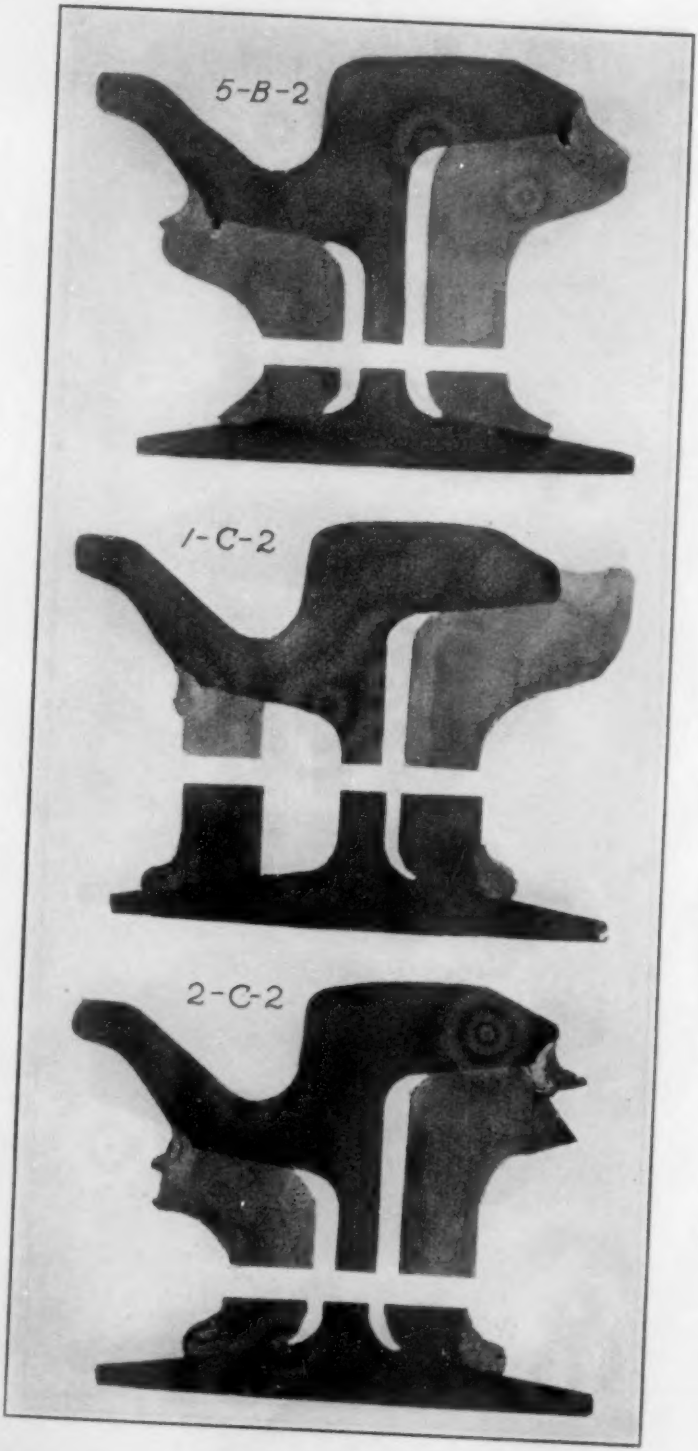


Fig. 20

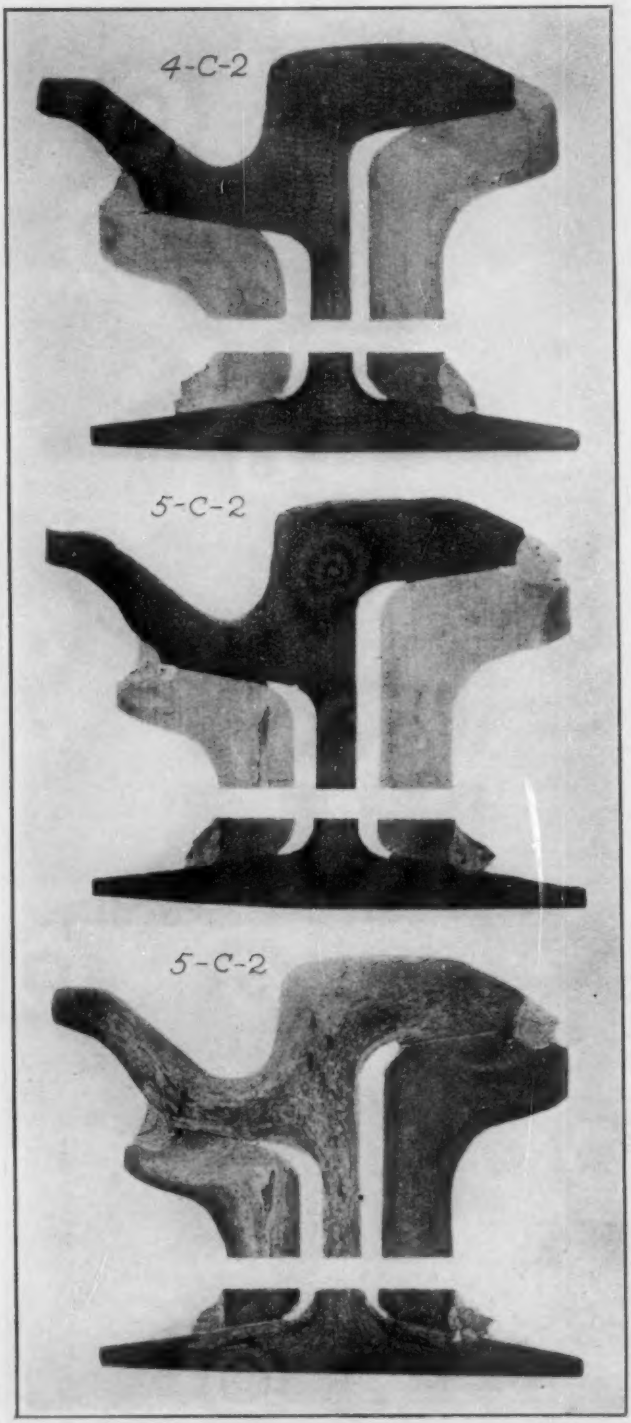


Fig. 21

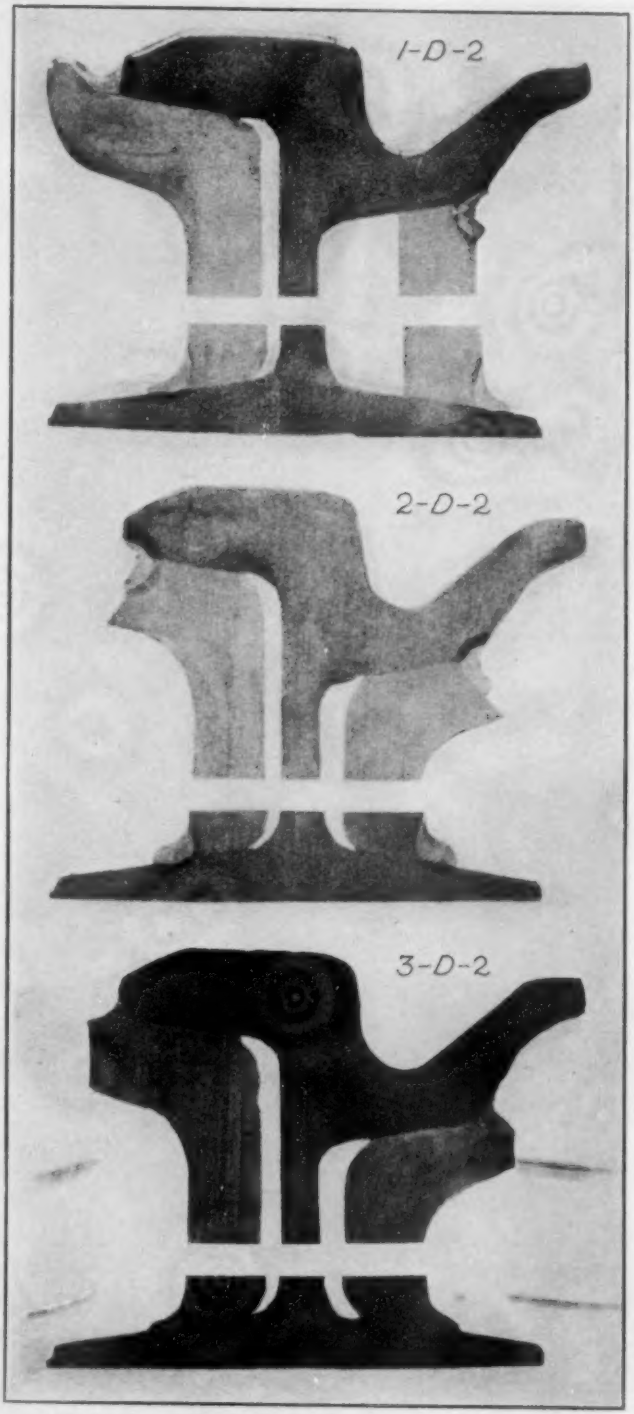


Fig. 22

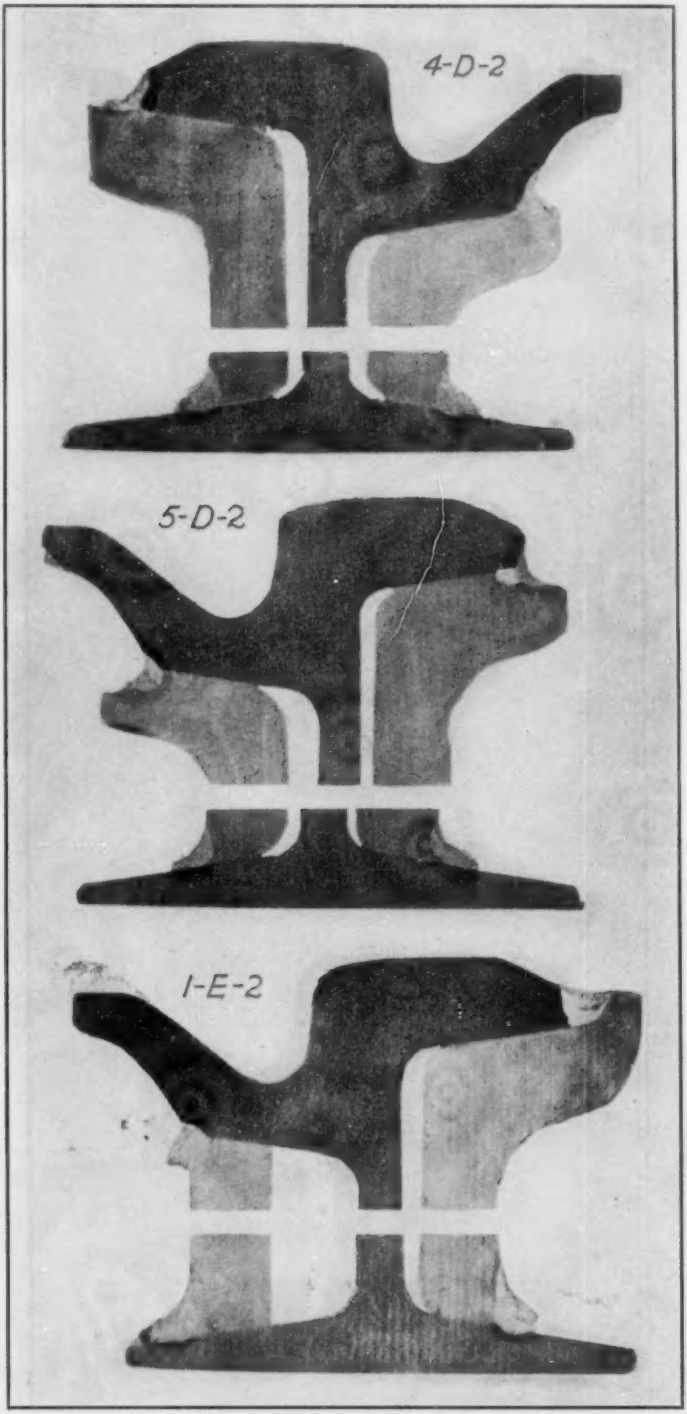


Fig. 23

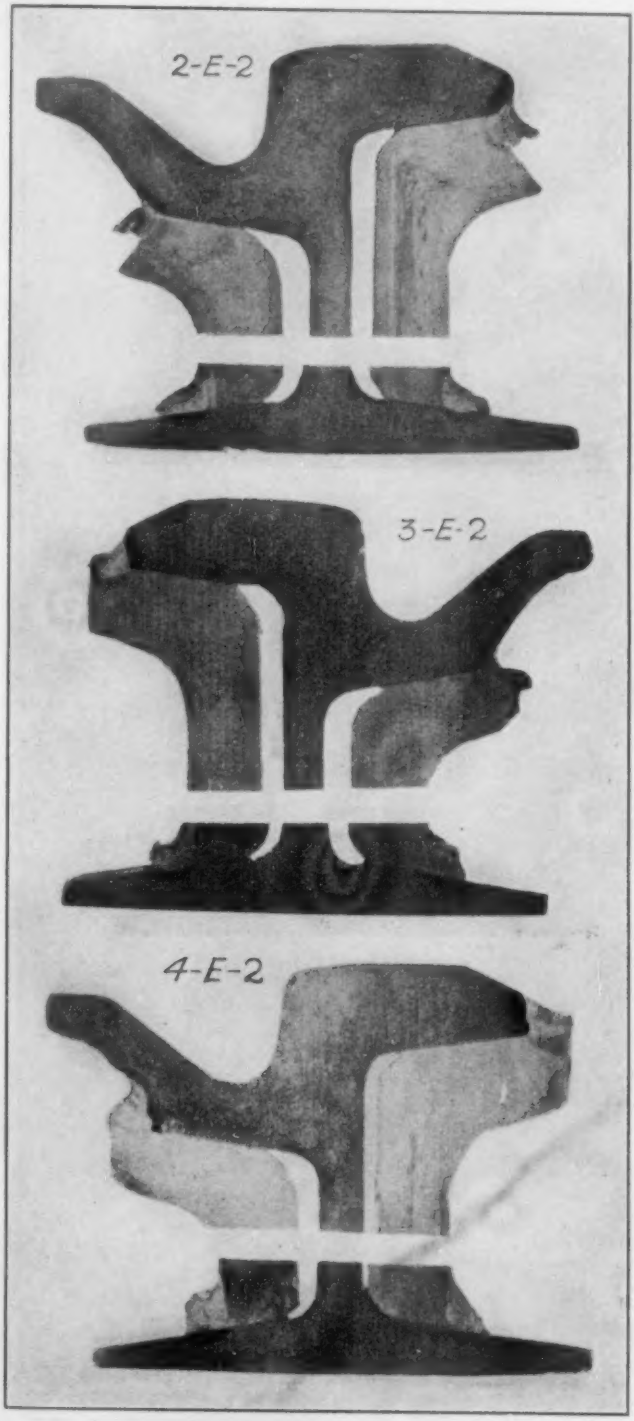


Fig. 24

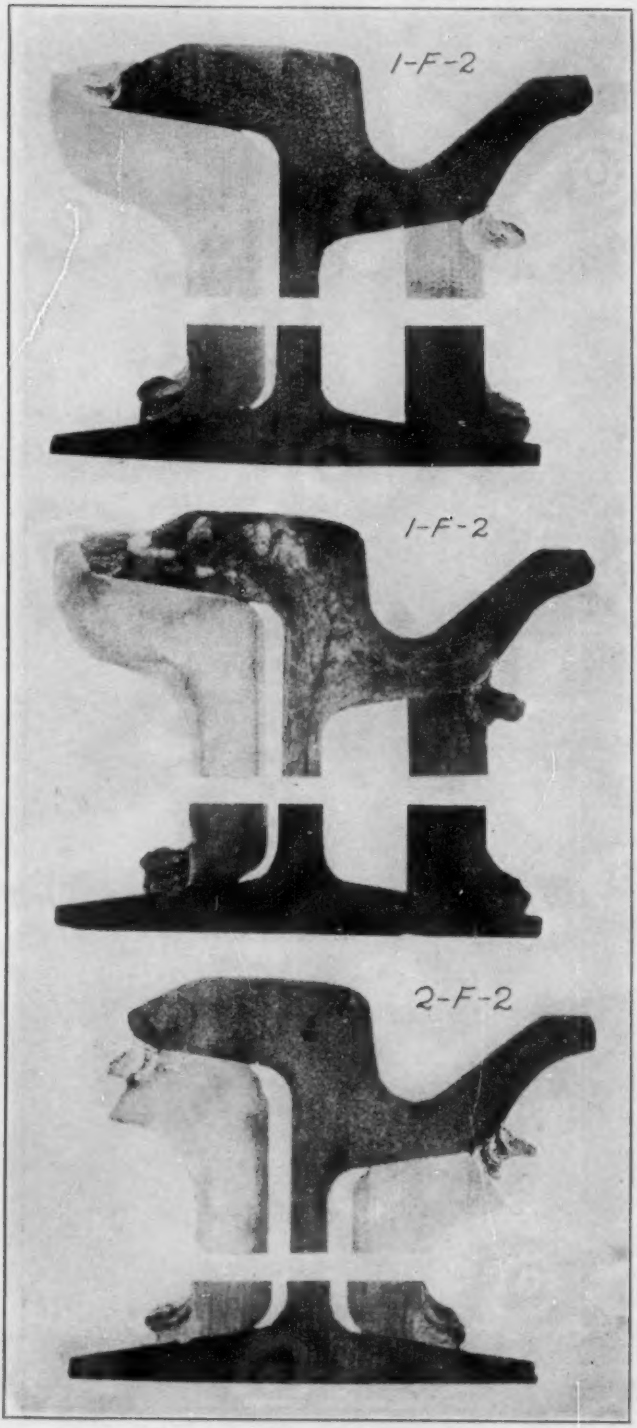


Fig. 25

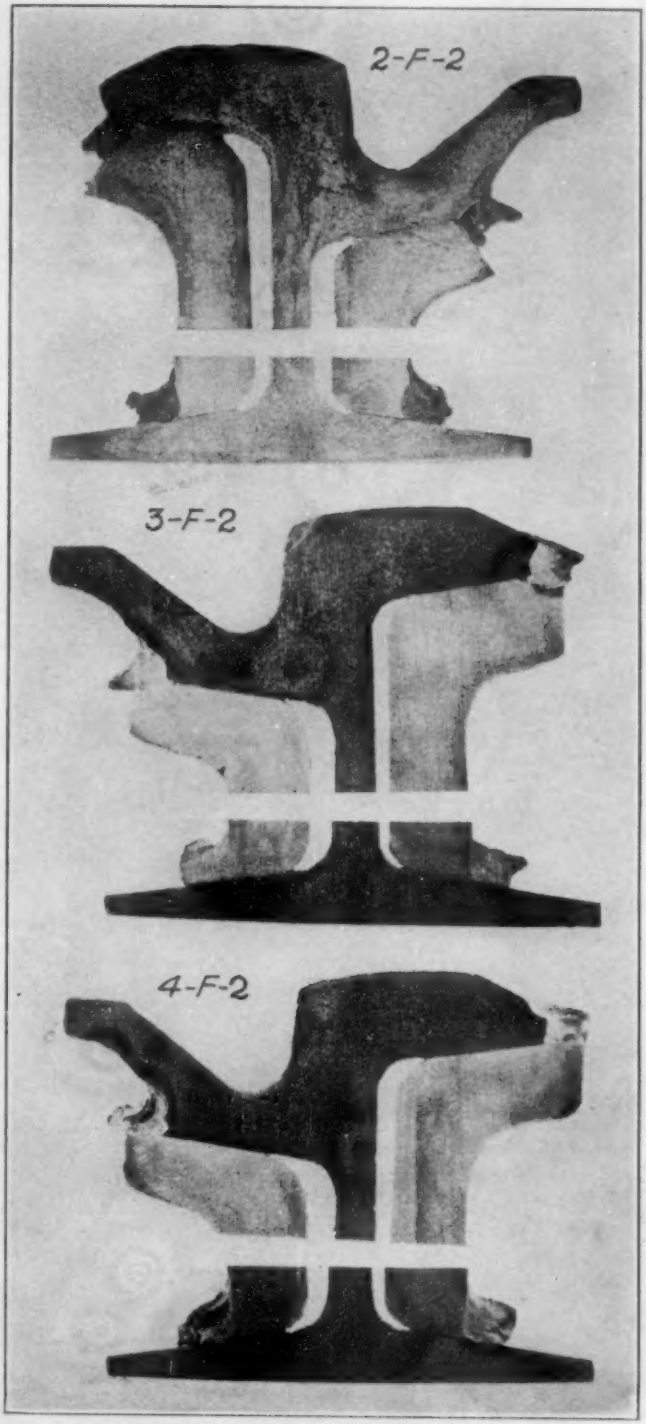


Fig. 26

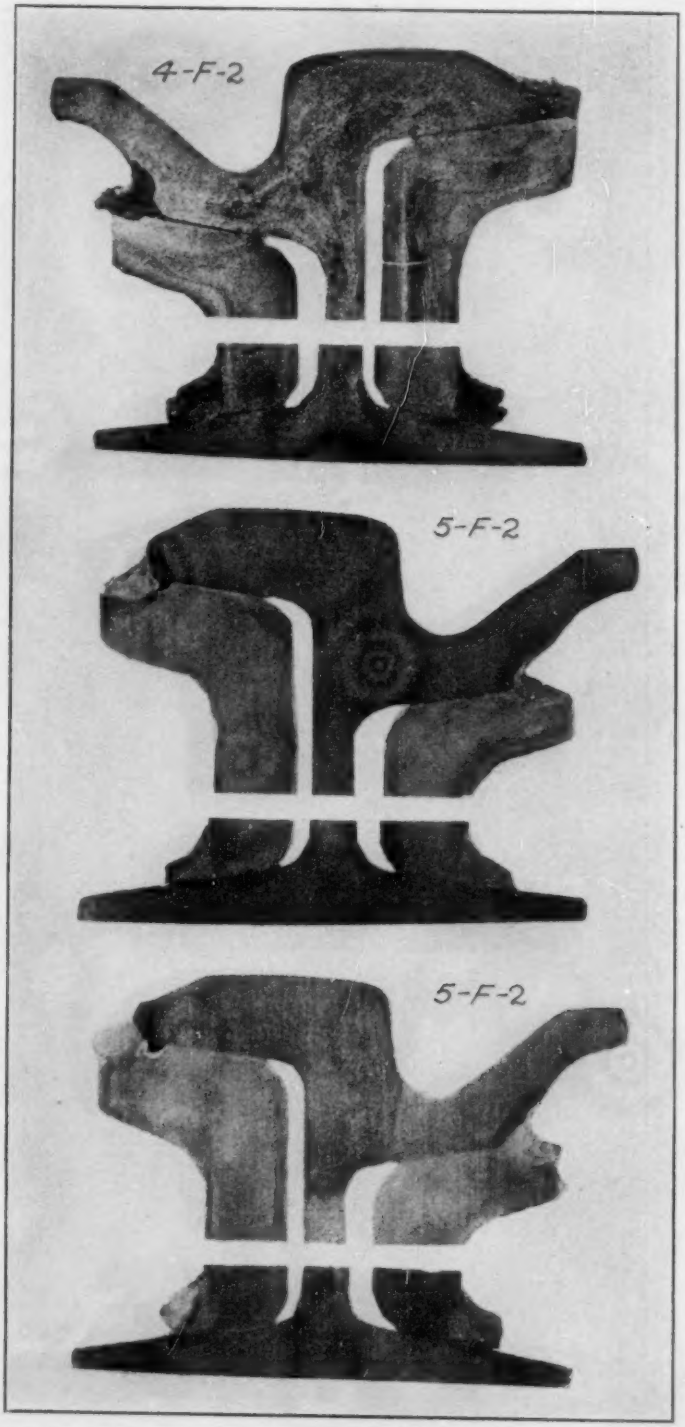


Fig. 27

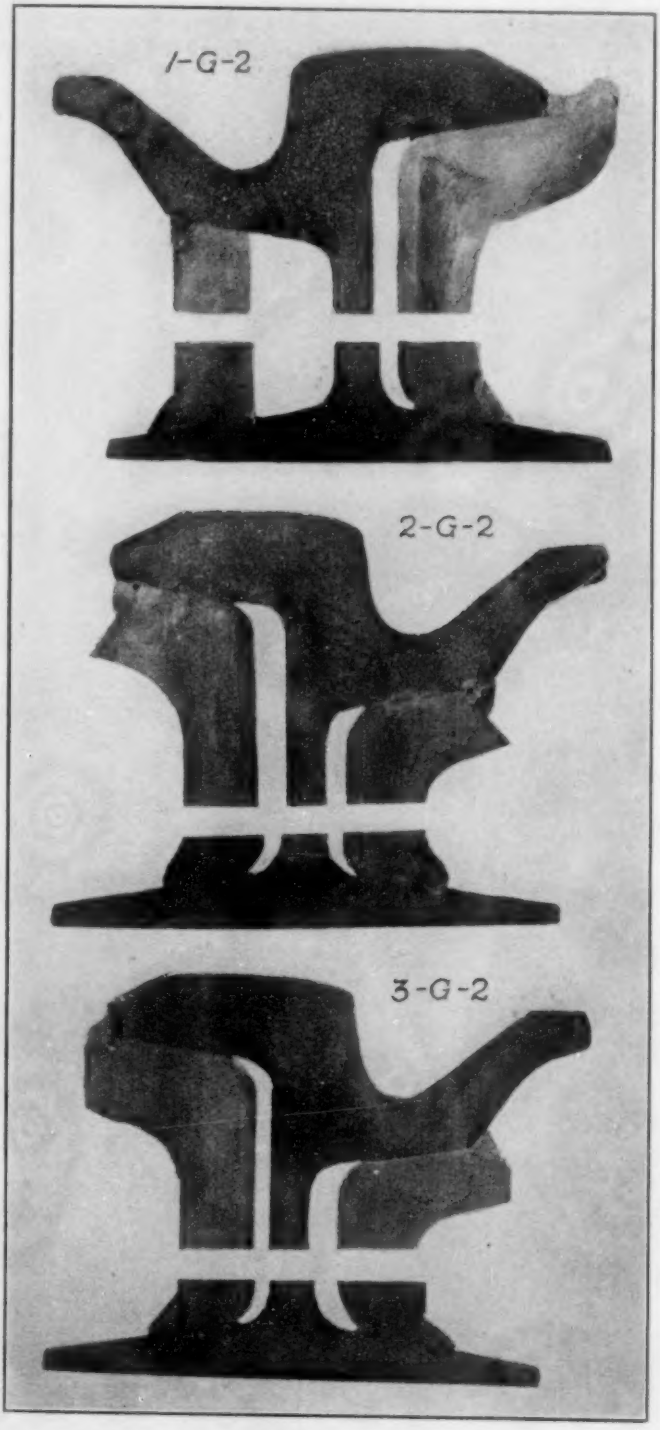


Fig. 28

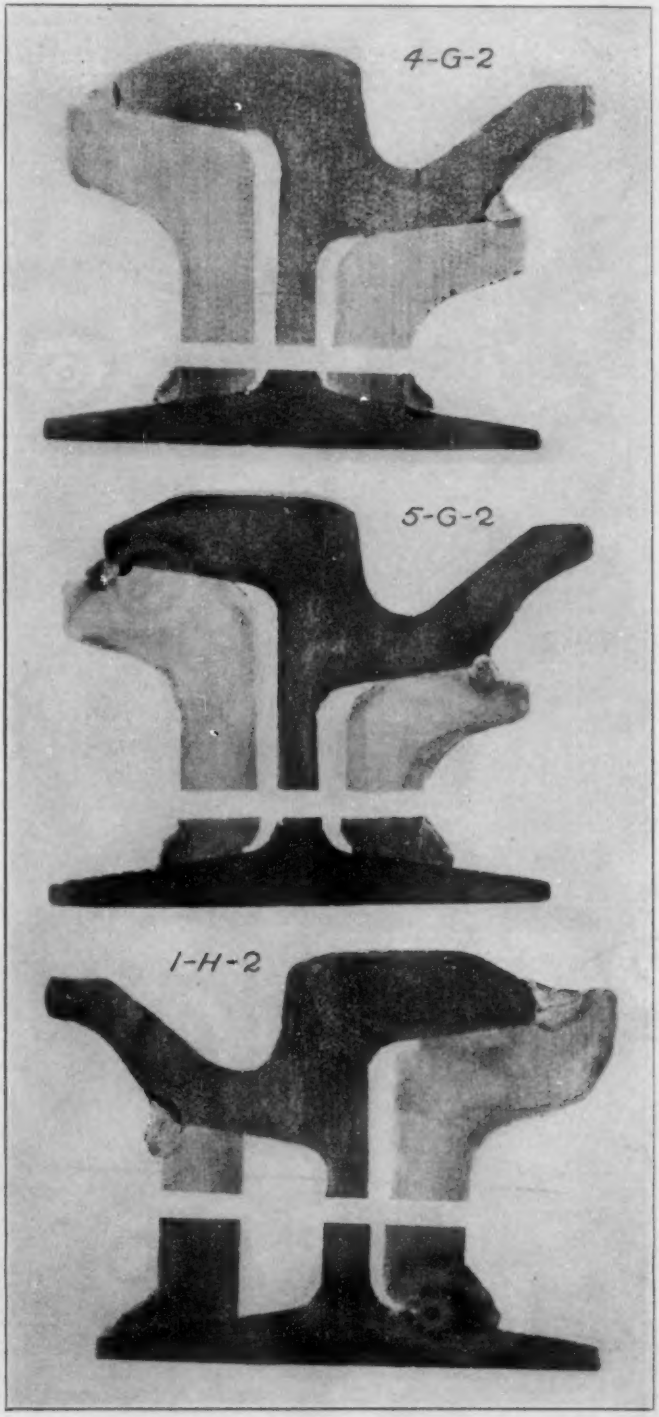


Fig. 29

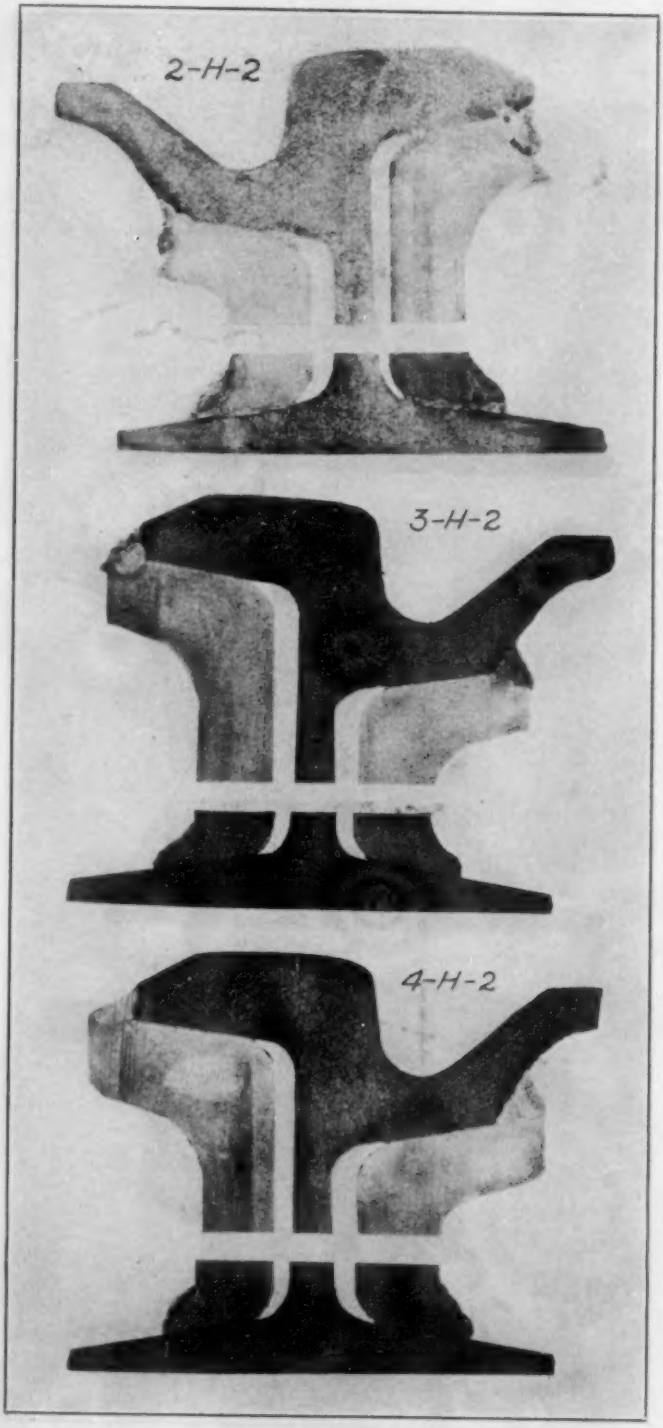


Fig. 30

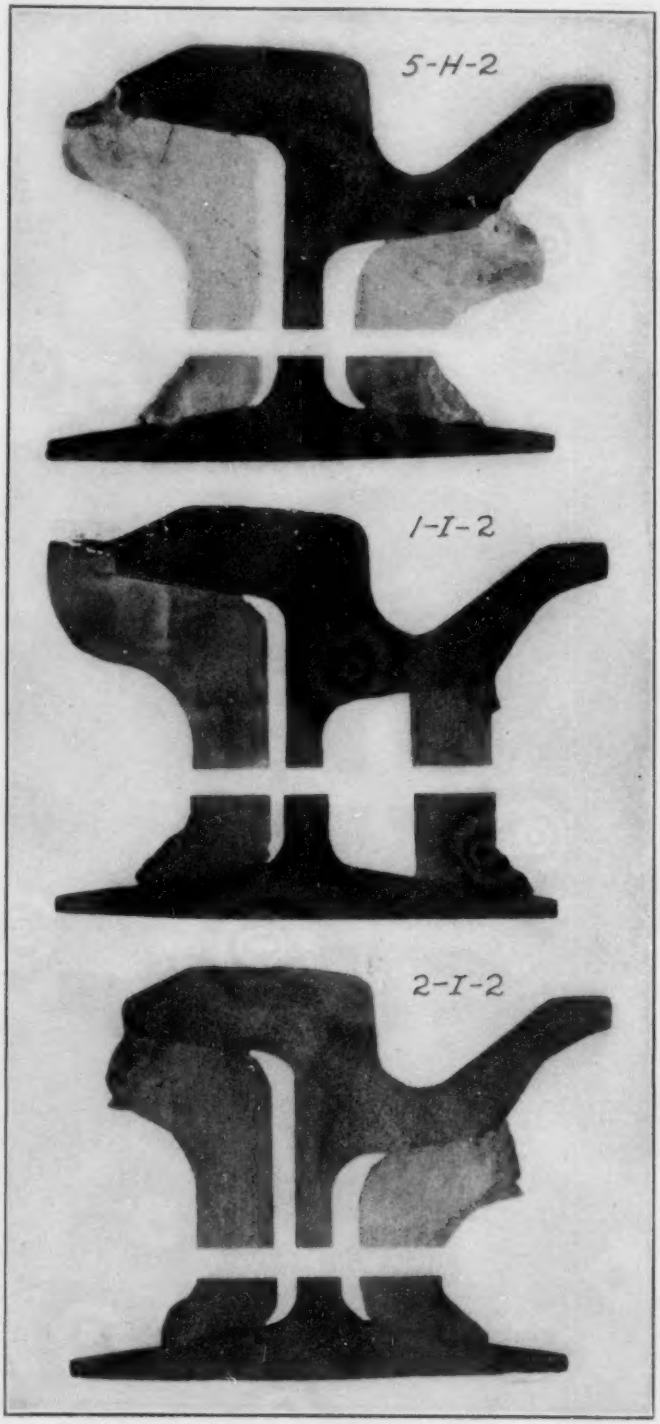


Fig. 31

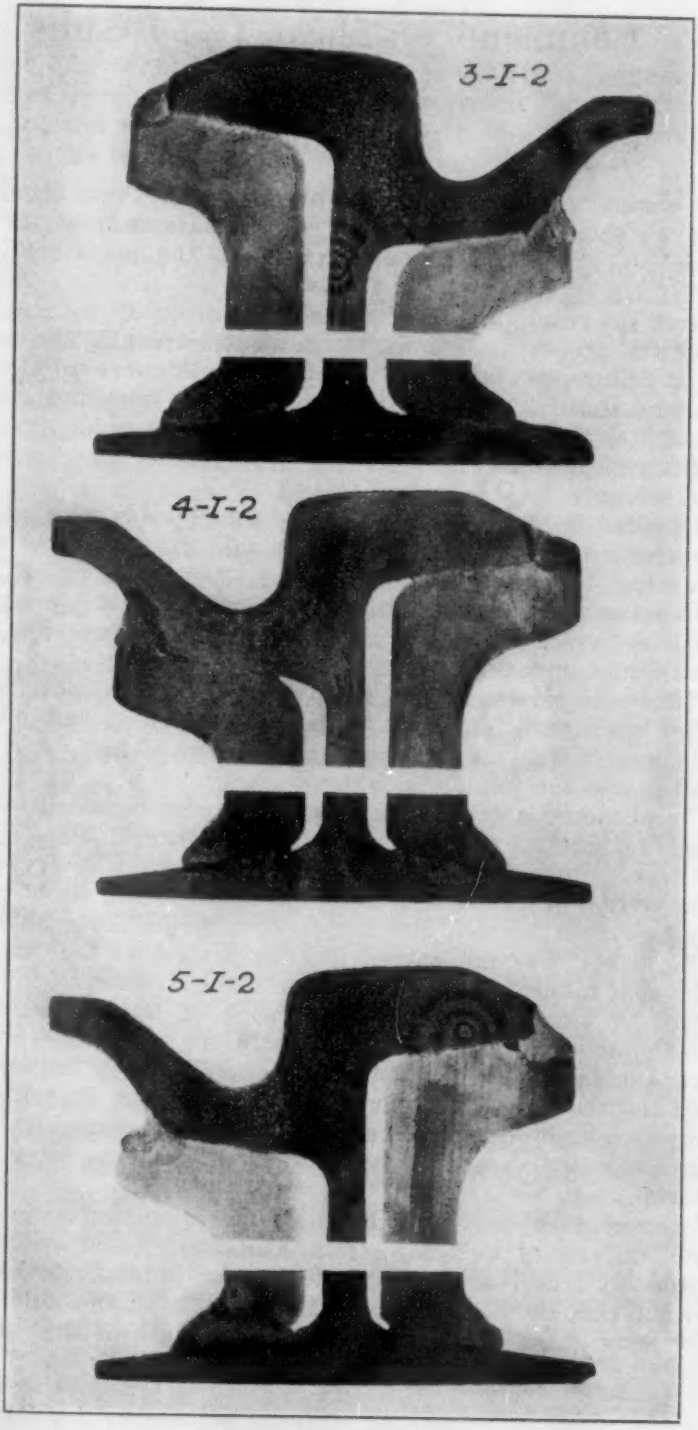


Fig. 32

Comments on Shear Test Results

By H. L. Whittemore
of Bureau of Standards

In comparing the mechanical properties of these shear specimens we should attempt to base our comparison upon the values which presumably, most nearly measure the usefulness of the joint in the track.

From the results obtained at Lehigh University we may choose either the proportional limit, the ultimate strength, the deformation at failure, or even the slope of the stress curve up to the proportional limit. As strength is much more important than the ductility or the slope of the curve, we are probably justified in selecting either the values for the proportional limit or the ultimate strength.

If welded joints in the track failed under loads which exceeded the strength of the material we should compare the ultimate strengths.

If, on the other hand, a joint was unserviceable if it were permanently deformed, even slightly, then we should use the proportional limits in making the comparison.

Failures in service do not, in any great number, occur in either of the ways outlined above. Failures of welded rail joints are actually caused by the repeated application of loads due to cars passing over the joint.

The phenomena of failures of metals under repeated loads was called "fatigue" of metals by the late Dr. Henry M. Howe.

It seems probable that the failure of welded rail joints is caused in many cases by fatigue of the weld metal in the seam. Experiments on both ferrous and non-ferrous metals have shown that if the stress does not exceed a value known as the "endurance limit" that failure will not occur even if the stress cycle is repeated billions of times. Careful comparisons of the endurance limit with the other mechanical properties of the metal shows that for ferrous metals there is a definite relation between the endurance value and the ultimate strength and also with the Brinell number. As the strength of a metal can be estimated very closely from the Brinell number, apparently both measure the same property of the material.

Although there may be some difference in opinion as to whether or not failures of welded joints are directly caused by fatigue, it is probably true that fatigue is the major influence to be considered and that the best measure of the quality of the weld in these shear tests is the ultimate (shearing) strength of the specimens.

Telemeter Investigations

A description of the telemeter is given in the Third Progress Report of the Committee pages 52-57. Sample record charts are shown to illustrate the method used in recording readings by this device.

There follows reports by the Bureau of Standards relative to tests made in the street and on joints in repeated impact testing machine.

Department of Commerce.
Bureau of Standards,
Washington, D. C.

REPORT ON PRELIMINARY TESTS OF WELDED RAILS, BALTIMORE, MD., AUG. 2 AND 3, 1926.

The arrangements for the tests described below were made by the Committee on Welded Rails of the American Electric Railway Association in cooperation with the Capital Traction Company of Washington, D. C., and the United Railways and Electric Company of Baltimore. The tests were made on a little used piece of track of the United Railways and Electric Company, which furnished the test car, materials and personnel necessary for operation of the car and changing track conditions. The instruments for making the tests and personnel for operating them, were furnished by the Bureau of Standards. The instruments consisted of a six-element recording telemeter, arranged to use standard oscillograph films for making records. Transportation for the instruments was furnished by the Capital Traction Company.

Object of Tests

The object of the tests was to obtain a sufficient number of records to determine what part of the program of tests outlined by the committee at its meeting of June 29 at Bethlehem, Pa., and in subsequent correspondence, it would be necessary to carry out in order to cover the points which the committee desired to make. The points which it was desired to determine were: (1) stresses in general under service conditions, (2) effect of cupped joints, (3) effect of speed, (4) effect of paving, (5) stresses under similar conditions in different types of joints.

Types of Joints Tested

Tests were made in unpaved street on (1) unbroken rail, (2) bolted joint, (3) welded joint, (4) welded joint with a base plate, and (5) unbroken rail in paved street.

Condition of Roadbed

On account of rains the roadbed in the unpaved street was soft, and although the ties were tamped until the movement was very slight, the bending of the rail as the car passed over it was greater than it would have been if the roadbed had been dry. In any future tests at the same place it will be necessary to take this into consideration n comparing results. In the paved street the sup-

port for the ties had been much less affected by the wet weather than in the unpaved street.

Test Car

The test car number was 3719, weight 52,000 lb., truck centers 21 ft. apart and wheel centers 5 ft. 10 in. apart.

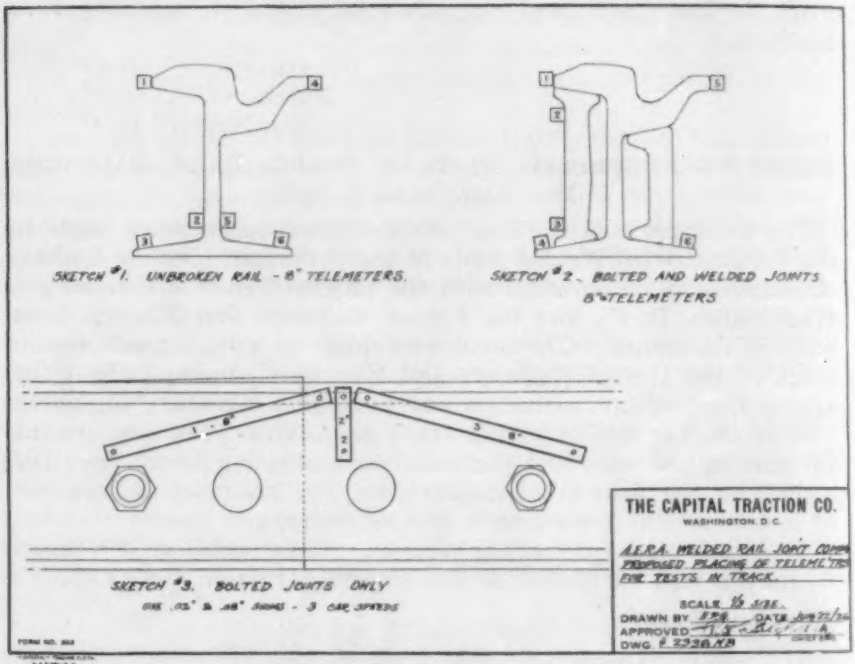

SKETCH #1. UNBROKEN RAIL - 6 TELEMETERS.
SKETCH #2. BOLTED AND WELDED JOINTS 6 TELEMETERS
SKETCH #3. BOLTED JOINTS ONLY
THE CAPITAL TRACTION CO.
WASHINGTON, D. C.
A.E.R.A. WELDED RAIL JOINT COMM.
PROPOSED PLACING OF TELEMETERS
FOR TESTS IN TRACK.
SCALE 1/2 SIZE.
DRAWN BY
APPROVED
DWG. # 2336-A

Fig. 33. Showing location of telemeters

Speed

The speeds were estimated at the time of the tests, and this resulted in a narrower range of speeds than was anticipated, but enough variation is shown to indicate whether the effect of speed is appreciable within the usual service limits. The speed in each instance was calculated from the records by using the timing line and the distance between wheel centers.

Placing of Instruments

The telemeters were placed on the rail as nearly as practicable in conformity with a Drawing, Fig. 33, of the Capital Traction Company dated June 22, 1926, except that in sketch 2, on account of limitations of space it was necessary to place gage 4 on the under side of the base instead of on top. All other positions were as shown.

Shims

In order to simulate cupped joints sheet iron shims were made to raise the wheel of the car as it passed and let it drop on the

rail through a distance equal to the thickness of the shim. The point of impact was kept as nearly as practicable at the center of the gage length. The shims were about 20 in. long with the approach end sloped to give a gradual rise to the wheel. The other end was cut off at right angles. The shims were attached to the track with screws, and while there was some difficulty in keeping them in place during the passage of the test car, this occurred mainly with the thinner sizes. The thicker ones gave no trouble.

Photographic Conditions

Standard oscillograph films were used for recording. Changes of film were made in a portable dark room set up at the site of the test. Little difficulty was encountered with stray light, but the prevailing high temperature, both at the time of the tests and during development, made handling of the films difficult and resulted in the obliteration of some traces. The bright sunlight also interfered with proper adjustment of the light spots from the oscillograph mirrors, especially the first day when records 1 to 11 were made. Gages 5 and 6 in records 1 to 11 failed entirely to make a trace on the film, although they appeared on the ground glass screen.

Operation the second day was greatly facilitated by placing the recorder in the rear end of a small truck instead of the touring car which was used the first day. In all 37 records were made, with 145 readable traces out of a possible 192.

Calibration of Instruments

The gages were calibrated before leaving the bureau and again upon their return while the sensitivity of the oscillographed vibrators was checked on the ground. The sensitivity of the vibrators was increased by jarring in transportation, but there was no appreciable effect on the gages themselves, either in transportation or during the tests. The effect on the vibrators came from slight release of tension brought about by change of position of the springs through jarring. The vibrators were newly installed and had had no time and use to age them properly. All but No. 1 showed an increase of sensitivity, and the final calibration at the increased sensitivity was used in calculating the stresses.

The damping of all of the vibrators stood up well throughout the trip with the exception of No. 2, in which one of the oil drops had partly pulled away from the strip. This caused No. 2 to introduce at times a harmonic of its own in the wave shape, although one oil drop and part of another was sufficient to prevent this from being sustained for more than a few cycles, and to prevent serious overshooting. All of the traces except No. 2 are believed to be substantially a true reproduction of the stress in the rail at the different points.

Evaluation of Records

To read the films they were placed on a ground glass and illuminated from the rear by light from a north window. This facilitated

following the traces where they overlapped. A steel scale was laid on the film with its ends placed where the trace indicated that the zero line should be, and the height of the maximum deflection measured to the nearest 0.5 mm. with another scale at right angles to the first. All of the readable traces were gone over in this way and the stresses calculated. After this operation had been completed once, it was repeated without reference to the first result and the two checked against each other. Where discrepancies were found they were traced and care given to ascertain what appeared to be the correct value. It is believed that the results of these measurements are substantially correct as showing the maximum value of the stress in each trace. In most of the traces this means the maximum shown during the passage of all four wheels. In some, however, only one or two wheel contacts are shown, so there is a question as to whether that shown is the maximum that was produced.

In Table 1 are shown the calculated results of stress and speed, also the shim thickness and type of joint. In using this table it should be kept in mind that Gage 1 in records 1 to 11 was on the head of the rail and would, therefore, show compression which is indicated by a minus sign. Gage No. 2 was some distance below the center of the web and showed tension which is indicated by a plus sign. Gage No. 3 was on top of the base near the edge and also showed tension. Gage No. 4 was attached to the lip and showed compression. Gages 5 and 6 were opposite Nos. 2 and 3, but the spots were displaced vertically so no traces of these were obtained.

In records 12 to 27, Gage 1 was on the head, Gage 2 just below the top seam on the plate, Gage 3 just above the bottom seam on the plate, and Gage 4 on the lower side of the base near the edge. Gage 5 was on the lip and Gage 6 on top of the base near the edge on the opposite side from Gage 4.

In records 29 to 34, all of the gages were placed across the joint between plate and head, Nos. 1 and 2 diagonally, and No. 6 (2-in. gage length) vertically.

Each trace was evaluated on the assumption that the elastic modulus of the rail material is 30,000,000 lb. per square inch. In the case of 29 to 34 the quantity measured was a slip or closing of a joint, at least in part, but this is shown in the table as an equivalent stress.

Discussion of Results

In general character the results are rather scattering in that under what appears to be similar conditions the values of stress obtained do not check as closely as might be expected. This is due in part, at least, to the fact that at the same car weights and speeds, exact conditions are not always repeated on account of differences in spring reaction, swaying of the sprung weight and nosing. However, the trend of the results is quite clear. At no place does it appear that the stress exceeded the safe working limit

of the material. The maximum shown where simple stress was concerned is 10,800 lb. per square inch, which was in the lip of the welded joint without a base plate.

In order further to study the stresses the arithmetical average of the stresses from each record was found and plotted against shim thickness. These curves, on the accompanying curve sheet, Fig. 34, indicate roughly the rate at which stress increases with increase of drop, and also give an idea of the relative stresses in unbroken rail, welded joint, and welded joint with base plate.

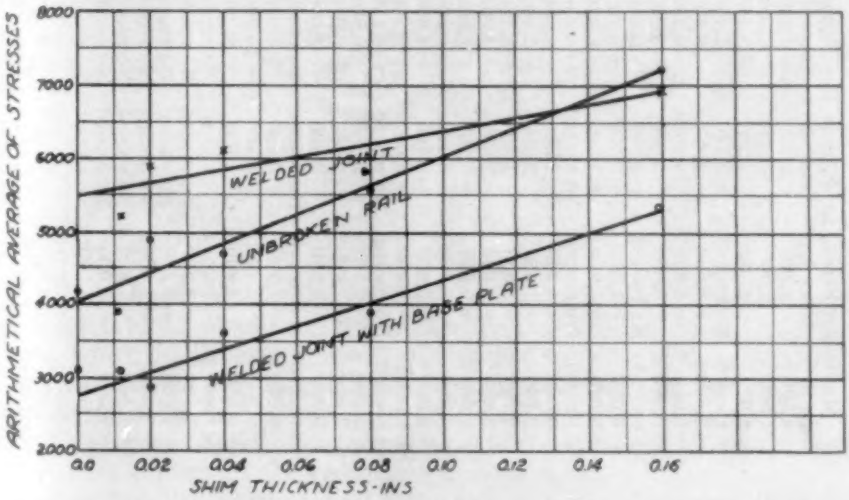


Fig. 34. Chart showing arithmetical average of stresses for different shim thicknesses

ARITHMETICAL AVERAGE OF STRESS READINGS FROM EACH RECORD

Shim Thickness, In.	Unbroken Rail	Welded Joint	Welded Joint with Base Plate
.00	4,200	No reading	3,100
.01	3,900	5,200	3,100
.02	4,900	5,900	2,900
.04	4,700	6,100	3,600
.08	5,600	No reading	3,900
.16	7,200	6,900	5,300

There is no marked evidence that the stress is affected by speed. Records 17 and 18, also 25, 26 and 27, indicate that the height of drop rather than the speed is the main factor. It must be kept in mind, however, that the impact in this case was produced by dropping the wheel. If it were produced by raising the wheel as it came in contact with an obstruction the effect of speed would be more evident.

Records 35, 36 and 37, while incomplete, do not indicate that the macadam paving offered an appreciable amount of support to the rail. The values of stress shown are substantially the same as those shown for the unpaved track.

TABLE 1

Record Number	Type of Joint	Shim Thickness, In.	Car Speed, ft. per sec.	Maximum Stress in Pounds Per Square Inch Shown by Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6
1	Unbroken rail	0.00	No record	− 4,500	+ 3,200	+ 3,300	− 7,000	No record	No record
2	Unbroken rail	0.00	23	− 4,000	+ 2,900	+ 2,800	− 6,500	No record	No record
3	Unbroken rail	0.01	21	− 4,000	+ 2,900	+ 3,300	− 5,400	No record	No record
4	Unbroken rail	0.01	21	No record	No record	+ 3,700	− 5,400	No record	No record
5	Unbroken rail	0.02	22	− 5,000	+ 3,600	+ 4,200	− 5,800	No record	No record
6	Unbroken rail	0.04	22	− 5,000	+ 3,300	+ 4,200	− 6,200	No record	No record
7	Unbroken rail	0.08	22	− 5,000	+ 5,000	+ 5,600	− 6,900	No record	No record
8	Unbroken rail	0.16	22	No record	No record	+ 6,500	No record	No record	No record
9	Unbroken rail	0.16	22	− 8,000	+ 4,300	+ 6,100	− 9,200	No record	No record
10	Unbroken rail	0.16	23	− 8,000	+ 5,000	+ 7,000	− 8,900	No record	No record
11	Unbroken rail	0.16	No record	No record	No record	No record	No record	No record	No record
12	Welded joint with base plate	0.00	24.5	− 3,000	− 2,300	+ 2,300	+ 3,800	− 5,800	+ 3,600
13	Welded joint with base plate	0.01	24.5	− 2,000	− 1,400	+ 2,200	+ 3,900	− 5,400	+ 3,600
14	Welded joint with base plate	0.02	25.5	− 2,000	− 1,500	+ 1,800	+ 4,300	− 4,400	+ 3,200
15	Welded joint with base plate	0.04	25.5	− 2,800	− 2,000	+ 1,800	+ 4,000	− 6,300	+ 5,100
16	Welded joint with base plate	0.08	27.0	− 3,000	− 3,600	+ 1,900	+ 5,000	− 5,400	+ 5,800
17	Welded joint with base plate	0.16	25.0	− 4,000	− 2,900	+ 3,700	+ 6,200	− 6,300	+ 7,200
18	Welded joint with base plate	0.16	16.0	− 4,000	− 2,900	+ 3,700	+ 4,600	− 8,100	+ 9,000
19	Welded joint with base plate	0.16	28.0	No record	− 4,300	+ 3,600	+ 6,300	− 6,800	+ 7,200
20	Welded joint	0.00	25.5	No record	No record	No record	+ 6,150	− 8,100	+ 4,500
21	Welded joint	0.01	25.5	− 5,000	− 2,500	+ 2,800	+ 6,900	− 6,700	+ 7,200
22	Welded joint	0.02	24.5	− 6,000	− 2,900	+ 3,700	+ 6,900	− 8,100	+ 8,100
23	Welded joint	0.04	25.0	− 6,000	− 2,900	+ 3,900	+ 6,900	− 8,100	+ 9,000
24	Welded joint	0.08	25.5	No record	No record	No record	No record	− 9,000	+ 9,000
25	Welded joint	0.16	25.5	− 6,000	− 2,900	+ 5,600	+ 8,900	− 10,800	+ 9,000
26	Welded joint	0.16	18.5	− 6,500	− 2,700	+ 5,400	+ 10,000	− 9,000	+ 9,000
27	Welded joint	0.16	28.0	− 6,500	− 2,800	+ 5,600	+ 9,200	− 7,200	+ 7,200
28	Bolted joint	0.00	No record	No record	No record	No record	No record	No record	No record
*29	Bolted joint	0.00	23.5	− 1,500	− 4,300	No record	No record	No record	+ 3,800
30	Bolted joint	0.01	22.5	− 1,500	− 6,500	No record	No record	No record	+ 5,400
31	Bolted joint	0.02	23.5	− 1,500	− 7,000	No record	No record	No record	+ 7,600
32	Bolted joint	0.04	23.5	− 1,500	− 7,600	No record	No record	No record	+ 9,500
33	Bolted joint	0.08	23.5	− 1,500	− 10,000	No record	No record	No record	+ 13,000
34	Bolted joint	0.16	22.5	− 1,500	− 11,000	No record	No record	No record	+ 12,000
35	Unbroken rail, paved street	0.00	No record	− 4,000	No record				
36	Unbroken rail, paved street	0.08	22.5	− 3,000	+ 8,000				
37	Unbroken rail, paved street	0.16	23.5	No record	+ 8,700				

*2 inch gage No. 6.

SUMMARY

Telemeter Tests on Unbroken Rail in Impact Machine

In order to obtain some information as to the stresses developed under different heights of drop in the impact machine and to compare these with stresses found in service, a series of tests was made on a piece of unbroken rail with gages clamped on each edge of the base.

Twenty-five records were taken, all readable, but on account of poor photography, not suitable for reproduction. The average stress in the base of the rail for different drops are shown below.

Drop in Inches	Ft. Lb.	Average Stress #/□"	$\sqrt{\text{Height of Drop in Ft.}}$	Stress Ratio $\frac{\text{Stress}}{\sqrt{\text{Drop in Ft.}}}$
0.25	8.3	5,700	0.144	39,800
0.50	16.6	8,800	0.204	43,000
0.75	24.9	9,600	0.250	38,500
1.00	33.2	11,000	0.288	38,000
2.00	67.0	13,000	0.408	32,000
3.00	100.0	15,500	0.500	31,000
4.00	133.0	17,000	0.575	29,700
5.00	166.0	21,200	0.648	33,000
6.00	200.0	28,000	0.707	39,000

Columns are also included showing the foot-pounds of energy delivered by the hammer, the square root of the height of drop in feet, which is directly proportional to the velocity with which the hammer strikes the rail and the ratio of stress to square root of height of drop.

The stresses observed approximate the maximum found in service with a drop of the hammer of about 1 in.

From the values of stress, drop and energy, it appears that at first the increase of stress is approximately proportional to the square root of the height of drop rather than to the energy. After the drop exceeds 1 in., however, this no longer holds, as is indicated by the ratio given in the last column.

COMMUNICATION FROM O. S. PETERS, ELECTRICAL ENGINEER,
DEPARTMENT OF COMMERCE,
BUREAU OF STANDARDS,
WASHINGTON,

Feb. 24, 1927.

It would not be safe to conclude from these tests what the stress would be at the rail opening, as the strain there is concentrated, whereas in the unbroken rail it is distributed. We expect to find out something about the distribution of stress in joints by measurements with short gage lengths.

There is no way to tell what the effect on stress would be from changing the weight of the hammer, except to try it.

The velocity of the hammer in feet per second at the time of impact is $V = 8.02 \sqrt{\text{height of drop in feet}}$ if friction is neglected. The friction effects, I think, are practically negligible on account of

the relatively low velocity, heavy weight of the hammer and looseness of the guides.

There are no formulas that I know of other than the foregoing involved in the tabulation. The ratio shown in the last column should be constant if the stress is proportional to the velocity at the time of the impact.

COMMENTS FROM BUREAU OF STANDARDS*

March 4, 1927.

Mr. Wm. Spraragen, Secretary,
Committee on Welded Rail Joints,
29 West Thirty-ninth Street,
New York City.

Subject: Stresses in a Rail Due to a Falling Weight.

Dear Sir:

1. The data given in the letter of Feb. 12, 1927, from O. S. Peters of this bureau to you, on the stresses developed in a rail supported on a span of 22 in. by a tup weighing 400 lb. and dropping from various heights, have been compared with the formula given on page 28 of Progress Report No. 4, Committee on Welded Rail Joints.

2. The stresses indicated by that formula are much higher than those found by Mr. Peters. It was indicated in paragraph 4 of that discussion that the energy of the blow was not entirely used in deflecting the beam, but some of it was spent in accelerating the anvil and supports. It is a matter of observation that the whole mass does move when the tup strikes the rail. Consequently, in the inertia factor:

$$n = \frac{1 + \frac{17W}{35P}}{\left(1 + \frac{5W}{8P}\right)^2}$$

the quantity W must have a value greater and probably many times greater, than the weight of the rail between supports.

3. In order to see whether a formula of this type can be used to represent the stresses observed by Mr. Peters, the value of n was computed for each height of drop by taking the observed stresses as the stress due to impact, T. These values of n were then averaged and the average value was found to be

$n = 0.166$, which corresponds to a value of

$W = 2600$ lb., which is about one-seventh of the total weight of the anvil, supports and rail.

4. With this value of $n = 0.166$, the values of stress due to im-

*This analysis of the stress in the rail under impact was made by Dr. A. H. Stang, Engineer-physicist U. S. Bureau of Standards.

pact, T, were computed for various heights of drop of the tup. These values have been plotted as the full line curve of Fig. 35. The observed stress values are also shown on this figure by circles.

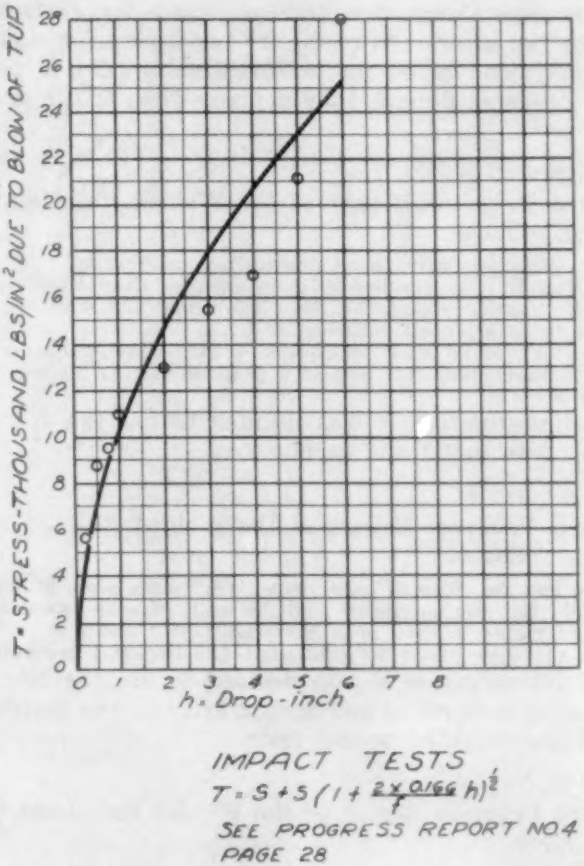


Fig. 35. Curve showing stress due to various heights of drop

The so-called "theoretical curve" appears to represent the observed values as well as any smooth curve that might be drawn.

5. The approximate formula, as given by Mr. Fehr on page 29 of the above mentioned Progress Report, gives values very close to those given by the previous formula. This equation becomes

$$T = S\ (\frac{2nh}{f})^{\frac{1}{2}} = 10280\ (h)^{\frac{1}{2}}$$

and is a very convenient formula to use. The plot of this curve practically coincides with that given in Fig. 35.

Respectfully,
GEORGE K. BURGESS, Director.

Program of Additional Investigations Proposed by Committee

Selection of Joint Plates:

The Executive Committee decided to use the carbon arc hand feed system two layers and metal arc two layers for making up the full size specimens called for in Investigation No. 2, published in the Third Progress Report. Joint plates Nos. 6, 7, 8 and 9 in Fig. 36 will be used.

Investigation No. 3:

The Third Progress Report of the Welded Rail Joint Committee reads as follows:

Object: To compare the value of preheating, postheating.
General: Nine full size specimens (three each for drop, tensile and repeated impact) shall be made of each variable given below with wire and joint plates selected as a result of Investigations 1 and 2.
Variables: (1) Make nine specimens without preheating or annealing, (2) Repeat 1 preheated, (3) Repeat 1 postheated, (4) Repeat 1 preheated and postheated.

On this investigation it was decided to use the No. 7 type of joint, using both metal and carbon arc.

Investigation No. 4:

The Third Progress Report of the Welded Rail Joint Committee reads as follows:

Object: To test the value of base plates. (⅜" plain plate 9" wide.)
General: Six full size specimens shall be made of each variable below with wire and joint plates selected from Investigations 1 and 2.
Variables: (1) Base plates not preheated, (2) Repeat 1 preheated.

For this investigation it was decided to use the No. 7 type of joint and using both metal and carbon arc. It was decided to make cross bend and repeated impact tests.

Investigation No. 5:

The Third Progress Report of the Welded Rail Joint Committee reads as follows:

Object: To compare the merits of the different methods used in securing tight fit between rail heads.
General: Six full size specimens shall be made of each type with wire and joint plates selected from Investigations 1 and 2.
The following methods shall be used for securing tight fit: (1) Standard drift pin without the use of inserts, (2) with use of inserts, and (3) two pressures with use of jacks.

For this investigation it was decided to use the carbon arc hand feed method two layers using the No. 7 type of joint. It was decided to make cross bend and repeated impact tests.

Strain Gauge Tests

In order to determine critical points where stresses are greatest in the seam welded type of joint an investigation was proposed by Professor Whittemore of the Bureau of Standards for taking a series of strain gauge readings in different parts of a rail joint when loaded at the center and supported at the two ends. These

measurements will be made by the Rensselaer Polytechnic Institute, and Catholic University. The joints will be furnished by the Boston Elevated Railway Co., and the United Railways & Electric Co. of Baltimore.

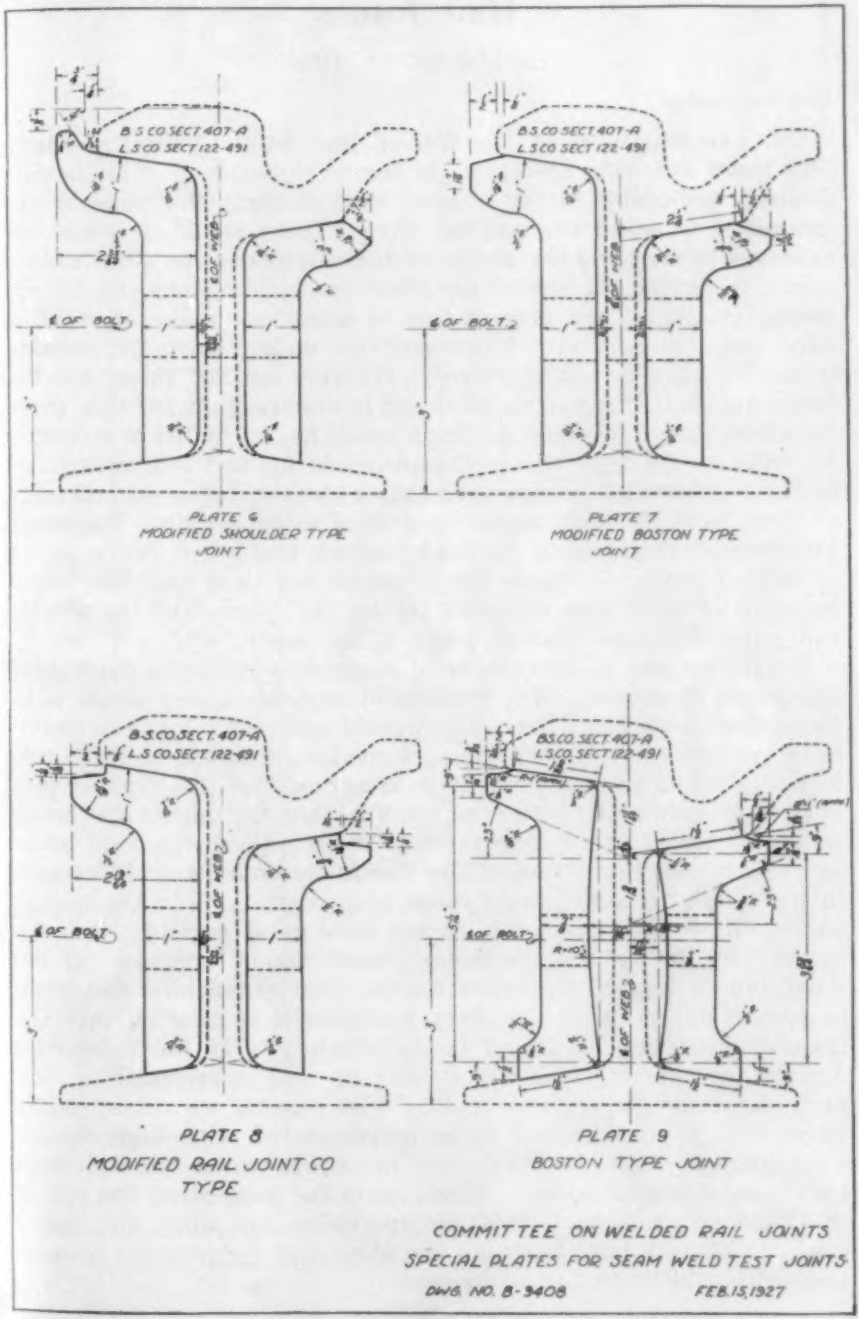


Fig. 36. Special plates to be used in additional tests of committee

BUREAU OF STANDARDS

Suggested Program for Strain Gage Measurements of Welded Rail Joints

OCTOBER 19, 1926

Workmanship:

The previous work of the Welded Rail Joint Committee shows that there are wide variations in the workmanship. This is particularly noticeable in the tests of welded specimens made by the committee to select the welding wire. There would be many advantages in studying the design of the side plates for seam welded joints, in having the committee select one welding process, for example, the metal arc process and in using one make of welding wire and one operator. The conditions under which the welding is done should be standardized. Whether or not these are the best conditions that can be produced is unimportant for this work. An effort should be made to obtain welds having uniform strength. In order to see that the workmanship is up to the standard set by the committee it is suggested that a piece of rail steel and piece of steel from the side plates be welded using a single Vee weld. These specimens should be made before and after every group of welded joints. If these specimens do not show that the workmanship is up to the standard set by the committee the welded rail joint should be discarded and others made.

We see no way to make tests of specimens cut from the welded rail joints themselves. The welding of separate plates seems to be the only alternative. From the welded specimens made to determine workmanship, Charpy impact specimens should be made and tested in a Charpy machine. If it is agreed that the weakest part of the Vee weld is the bottom of the Vee, then the impact specimens should be tested by striking them in the middle of the weld metal so as to stress the bottom of the Vee in tension. Any differences in the welds probably would cause large variations in the impact value. As welded specimens do not have great ductility, it is believed that the impact specimens should not be notched. If desired, tensile impact specimens for the Charpy machine also could be tested, but to avoid too many variables it is believed that the transverse specimens would be satisfactory. If the committee desires, specimens could be welded up and corresponding impact and tensile specimens made. The results, we think, would show that a high impact value corresponded with high tensile strength and high ductility such as occurs when the specimen breaks outside of the weld. One reason for suggesting the use of the impact specimens is that the specimens are small and easily made. This test costs less than any other test for physical properties, with which we are acquainted.

Fig. 36. Special plates to be used in additional tests of committee

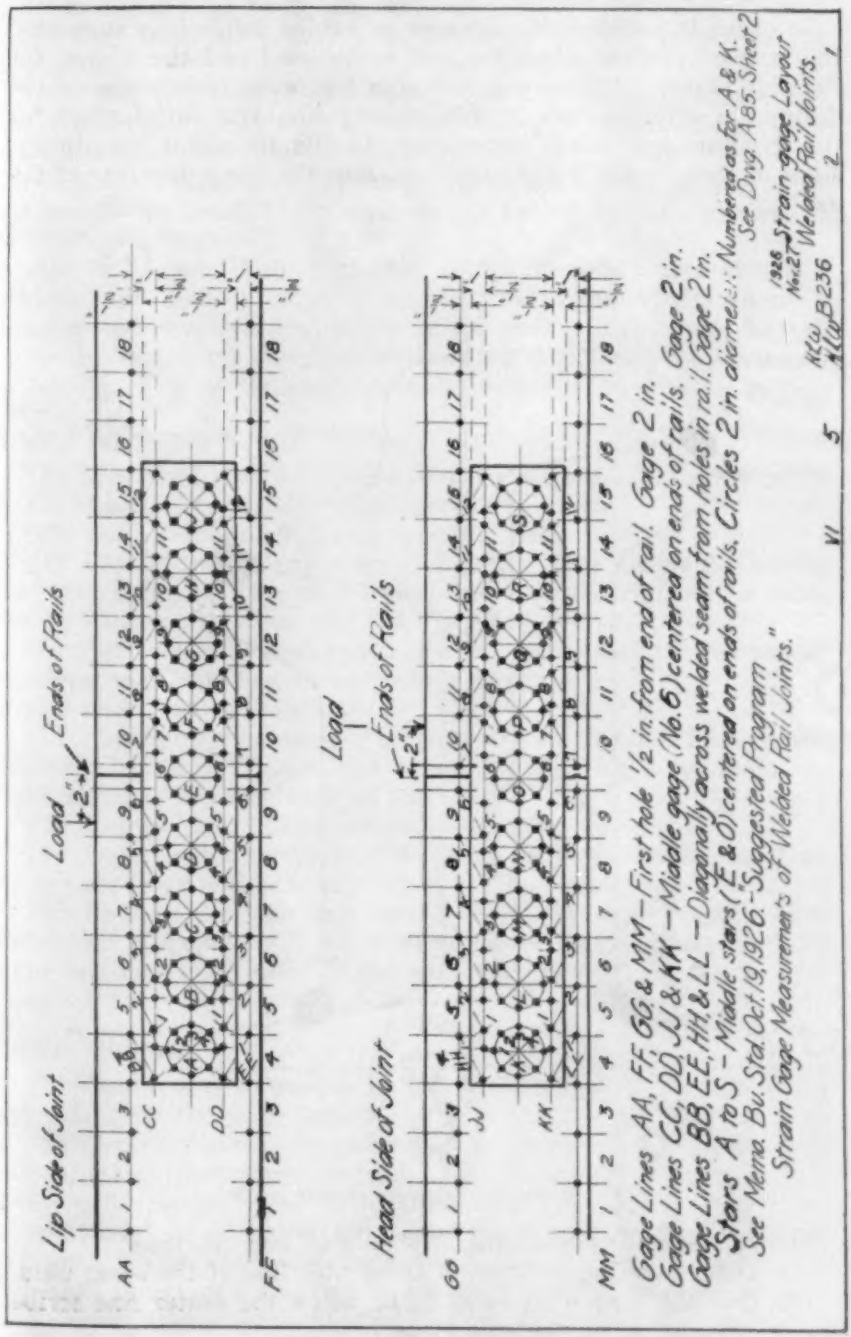

Lip Side of Joint
Load
Ends of Rails
2"
Head Side of Joint
Load
Ends of Rails
2"
Gage Lines AA, FF, GG & MM — First hole 1/2 in. from end of rail. Gage 2 in.
Gage Lines CC, DD, JJ & KK — Middle gage (No. 6) centered on ends of rails. Gage 2 in.
Gage Lines BB, EE, HH & LL — Diagonally across welded seam from holes in rails. Gage 2 in.
Stars A to S — Middle stars ("E" & "O") centered on ends of rails. Circles 2 in. diameter. Numbers as for A & K.
See Mem. Bu. Std. Oct. 19, 1926 - "Suggested Program
Strain Gage Measurements of Welded Rail Joints."
See Dwg. A85. Sheet 2
1926 Strain gage Layout
No. 2 Welded Rail Joints.
2
1
M.C.W.
4-16-B236
VI
5

Fig. 37. Chart showing method of making strain gage measurements

Stresses in Welded Joints:

In order to measure the stresses in welded joints it is suggested that the committee select the rail to be used and the design for the side plates. Probably one design following closely one of the designs in extensive use in this country would be satisfactory for this preliminary work. Specimens should be about the dimensions of those made for the tests to show the "present state of the art."

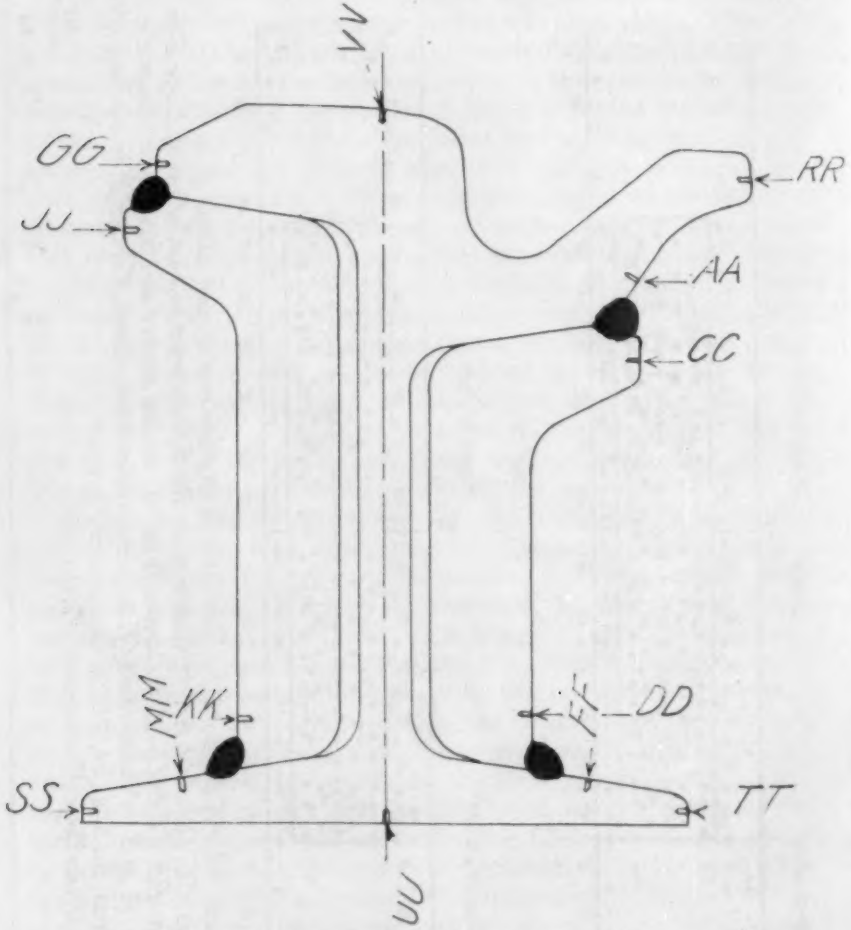


Fig. 38—Showing location of drill marks

Before assembling the joint, it should be laid off, thus:

(1) Determine the position of the center line of the seam weld.

(2) One-half inch above and ½ in. below the center line scribe line on the rail or on the side plate.

(3) Lay off 2-in. gage lengths on these lines for the full length of the plate.

(4) Lay off 2-in. gage lengths on the head and base of the rail for 6 in. beyond the flange in each direction.

(5) Lay off 2-in. "stars" 4 in. apart for the full length of the side plate.

The "star" consists of one vertical and one horizontal gage line and 2 at angles of 45 deg. to the horizontal. The middle of each gage line is at the center of the star.

(6) Lay off gage lines perpendicular to the axis of the rail from the base to the head. It is necessary to have a longer gage length for these readings.

(7) Drill gage holes with No. 56 twist drill. Use either a geared hand drill or better a dentist's flexible shaft driven by a small motor having a drill chuck at one end. Holes can be located either by laying off carefully with a double pointed center punch or by a jig having hardened bushings to guide the drill.

Gage Readings Before Welding:

(1) Read and record all gage lines before assembling the joint.

(2) Assemble the joint and tighten the bolts.

(3) Read and record gage readings.

(4) Lay off gage lines every 2 in. extending diagonally across the welded seam. One of the gage holes on the rail or the plate can be used for this line and the other one drilled.

(5) Record strain gage readings after welding all the seams and allowing the joint to cool to room temperature.

Transverse Test of Joint:

(1) Support the joint as a beam in the testing machine on the desired span, say 22 in.; load at the middle, say 2 in. from the vertical plane between ends of rails.

(2) Record strain gage readings for zero load.

(3) Load in increments of 2000 lb. or such increments that four or five readings will be taken before the joint takes permanent set.

(4) Remove the load and record the gage readings after each increment is applied. It is not necessary to continue taking strain gage readings after most of the gage lines show a marked permanent set.

Computations:

(1) Compute deformation in 1 in. by dividing the observed deformation by the gage length.

(2) Compute stress in rail and side plate by multiplying the deformation (inches per inch) by the modulus of elasticity (30,000,000 lb. per sq. in.). When the computed stress is above the proportional limit (yield point) of the steel these stresses are fictitious. The graphical method of obtaining stress from the readings taken on a star can be found in text books on mechanics. It does not appear probable that the readings on the stars will be as important as the readings taken along the seams.

We do not believe that the shearing stresses in the seams can be

computed from the diagonal strain gage readings, but they will show where the stress is high, and if they show a noticeable permanent set after removing the load they show that the seam has been permanently deformed and is likely to fail under increasing loads or under service conditions. With these data plotted to show stress vertically and distance along the seam weld horizontally it is believed that the committee can make changes in the design of the side plates so as to reduce the stresses in the seam weld where they are found to be excessive. It may be found advantageous to reduce the thickness of the plates at the ends or to cut away the metal of the plates at the ends for several inches, leaving a sort of a fishtail at the end of the plate.

The strain gage tests in the laboratory should be repeated on the modified design until the committee feels that a satisfactory stress distribution has been obtained. The specimens should be made and tested in the same way as specimens for the "present state of the art" series; that is, for conductivity, tensile, bend, drop and repeated impact. It is evident that in making these transverse tests in the laboratory the span can be adjusted to obtain approximately the stress distribution found in telemeter tests in the track. The specimens can be loaded at any place along the span. It is probable that if this is done it will be found that the maximum stresses occur when the load is near the middle of the span, but applied entirely to one of the rails.

Examination of the Ruptured Head of the Ethylene Tank*

S. W. MILLER†

A general report of the circumstances leading up to the rupture of this head was made on June 30, 1926, and published in *Mechanical Engineering* for August, 1926, pp. 845-846, and in the journal of the *A. W. S.*, September, 1926.

The ruptured head was cut off with a cutting torch about 2 in. beyond the head girth weld and sent to the Union Carbide and Carbon Research Laboratories for investigation and study. After careful consideration by all those interested, it was decided that the best method to pursue in the investigation was to take tensile test pieces from various parts of the head to see if any change had been made in the physical properties by the various processes to

Fig. 1. Partial interior view of tank head, showing positions of certain samples before removal (See Fig. 5 for assembly drawing)

which the head had been subjected. It was also decided that sections should be cut from various parts of the head to determine what change in thickness had been caused by the flanging operation, and that a number of macro and micro sections should be examined, as they might explain changes in physical properties, as well as show the general quality of the welds. Chemical analyses

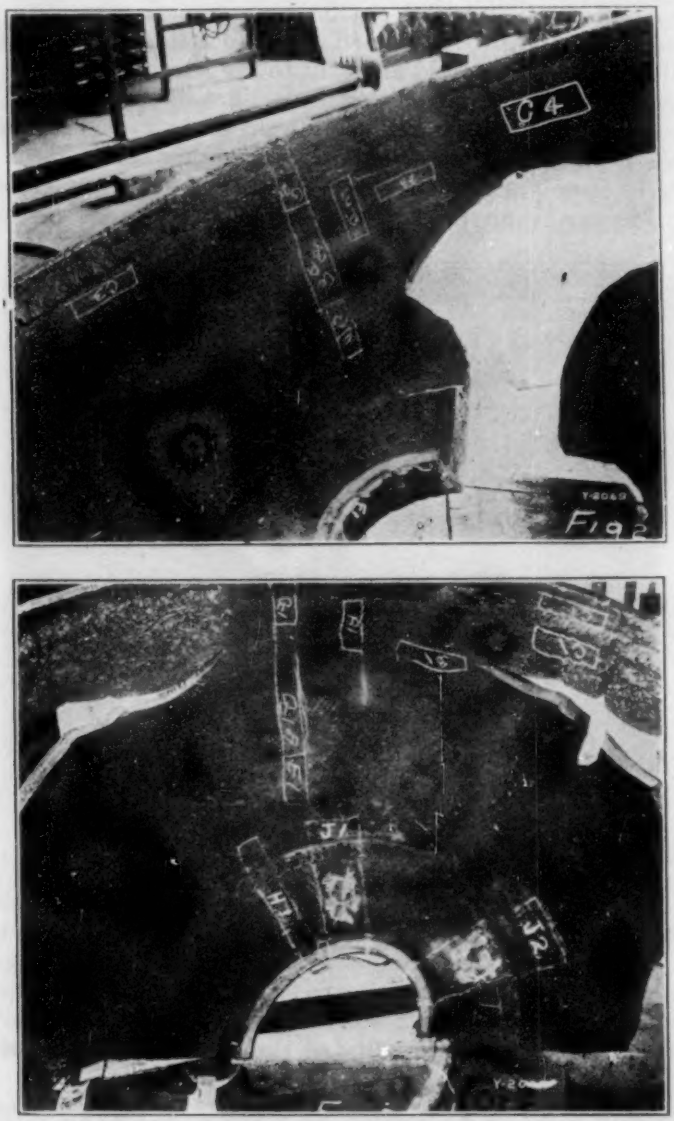
†Union Carbide and Carbon Research Laboratories.

*Presented at a joint meeting of the Metropolitan Section and Machine-Shop Practice Division of the A.S.M.E. with the New York Section of the American Welding Society, New York, Jan. 4, 1927.

Cuts loaned through courtesy of *Mechanical Engineering*. Abstracted from February issue of *Mechanical Engineering*.

were also decided upon, to be made from the head, the shell and the manhole flange.

In accordance with these ideas the general location of the test pieces was marked off with chalk on the head, and photographed as in Figs. 1 to 4, inclusive. While these photographs show the original chalk marks they do not show them all on one view, and in order that there may be more definite understanding of the exact relationship, Fig. 5 has been prepared, giving these all on one



Figs. 2 and 3. Partial interior views of tank head, showing positions of certain samples before removal (See Fig. 5 for assembly drawing)

sheet. Of course, Fig. 5 shows the test pieces as if they were in the undamaged head, but it is believed that this will make it more clear than could be done in any other way.

PHOTOMACROGRAPHS

These are shown in Figs. 6 to 14, inclusive. In the "C" specimens the ends were etched, Figs. 6 to 9, inclusive, to determine the general quality of the welds with regard to penetration and thoroughness of fusion. There are a few minor defects at the bottom of the vee, but they are unimportant because they are small

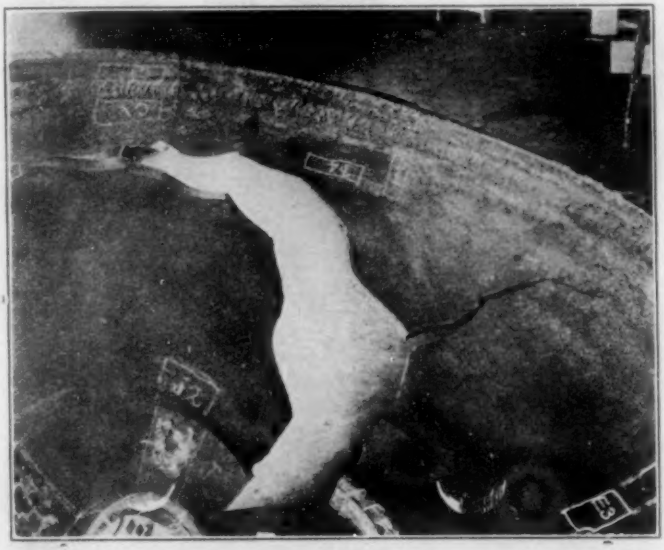


Fig. 4. Partial interior view of tank head, showing position of certain samples before removal. (See Fig. 5 for assembly drawing)

and local, and because they are more than made up for by the reinforcement.

In Fig. 6, showing section "C-1," the layout of the tensile test pieces "C" is shown. While it looks as if the test pieces were out of center with the center line of the section, yet the center of the length of the test piece is central with the center line, the curvature of the piece making it necessary to offset the stub ends of the test piece.

Figs. 13 and 14 show the thicknesses at various points of the sections taken through the manhole flange. This points to the necessity of taking into account this change in thickness and calculating the strength of the actual flange, and not assuming that the manhole flange has its nominal thickness.

The head was intended to be 1¼ in. thick, but it will be noticed that in no case was this dimension obtained in the spherical part of the head, although the minimum thickness is only about 0.04 in.

less than 1¼ in. In general, the head seems to have thinned down in the spherical part and to have gradually thickened up toward the knuckle, until an increase in thickness is seen amounting in section "I" to 0.18 in. at the end of the flange.

As to the effect on the welding of this thickening of the flange, it seems to emphasize the necessity of more beveling of the head on the inside so that the section of the vee on the head and on the shell are closely the same, especially with heavy plate.

CHEMICAL ANALYSES

	Mill test	Laboratory Tests		
		Head	Shell	Manhole flange
Carbon, per cent.....	0.18	0.22	0.09	0.17
Manganese, per cent.....	0.42	0.40	0.32	0.43
Phosphorus, per cent.....	0.011	0.018	0.013	0.010
Sulphur, per cent.....	0.030	0.033	0.019	0.020

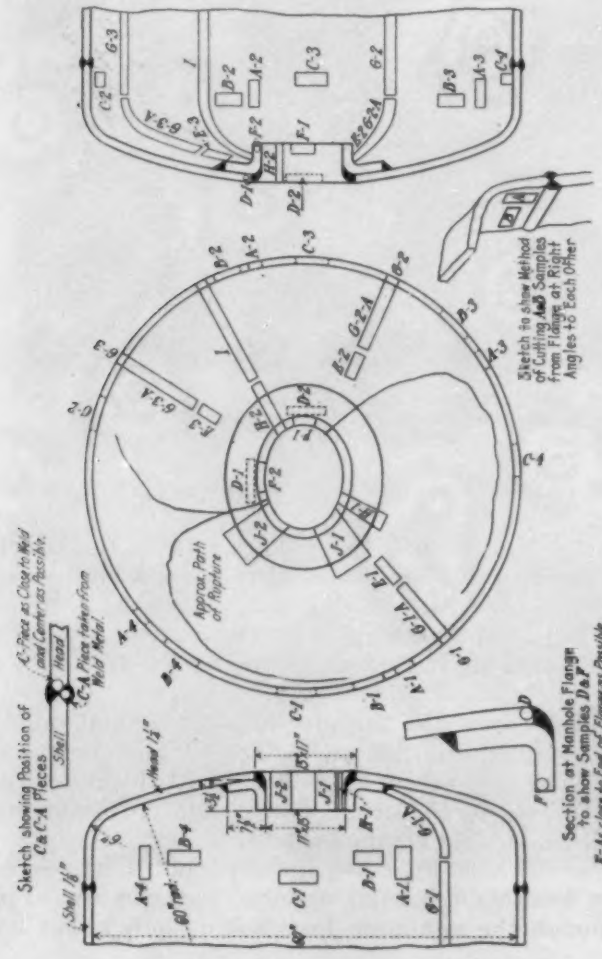

Sketch showing Position of C & C-A Pieces
C-Piece as Close to Weld and Center as Possible
C-A Piece taken from Weld Metal
Head
Shell
Approx. Path of Rupture
Sketch to show Method of Cutting A & B Samples from Flange at Right Angles to Each Other
Section at Manhole Flange To show Samples D & F
F-As close to End of Flange as Possible.
D-As close to Edge and Outside as Possible.
Head 1½"
Shell 1½"
60° Taper
60° Taper

Fig. 5. Assembly Drawing Showing Position of All Test Samples Taken as They Would Appear in Tank Head Before Rupture

Tensile Tests

Table 1 gives the results of the tensile tests, and it is seen that all of the test pieces from the head, regardless of their position, meet the requirements of firebox and flange steel in the Boiler Code in regard to tensile strength, yield point, and elongation, with the exception of test piece "A-1," which fails in the elongation by only 0.8 per cent. All of the reductions of area are also entirely satisfactory. The A. S. M. E. Pressure Vessel Code permits the use of the materials in Section II of the Boiler Code for the construction of pressure vessels.

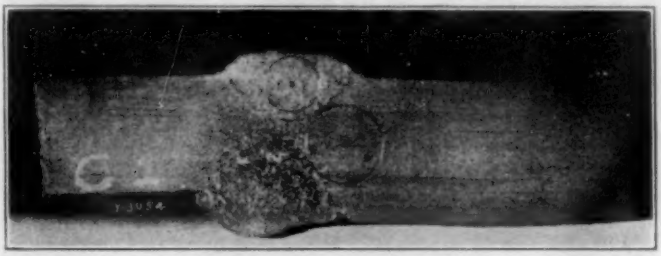


Fig. 6. Macroscopic View, Full Size, Showing Weld Between Head and Shell at Position "C-1"

(Note the good fusion of the weld and base metal, also the refinement of the grains on one side of the weld from the welding heat of the second side. The two circles denote the positions of the "C" and "C-A" samples. These were taken respectively from the base metal immediately adjoining the weld and from the weld metal itself.)

Fig. 7. Macroetched and Photographed, Full Size. Taken from Position "C-2" in Fig. 5

(Note the position of the inscribed circle as close to the weld metal and to the outside face of the tank head as the curvature will permit. All the "C" samples were taken in this general way.)

Fig. 8. Macroetching of Weld at Position "C-3"

Fig. 9. Taken from Position "C-4," Fig. 5. Macroetched to Show Position of Weld Metal

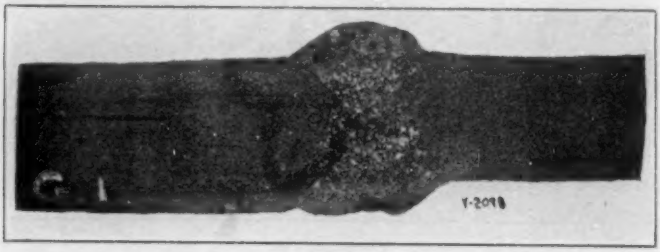


Fig. 10. Macroetching of Samples Shown at Position "G-1" in Fig. 5 to Show Quality of Weld

Fig. 11. Macroetching of Sample Taken at Position "G-2" in Fig. 5, Note the Good Fusion Along all Scarf Surfaces

Fig. 12. Macroetching of Sample Taken from Position "G-3"

The results of the "C" specimens show that, at least in double-vee welding in plate of this thickness, there is no change in the physical properties of the metal due to the welding heat. For many years one of the arguments of those opposed to welding has been that the base metal next to the weld must be injured by the welding heat. These results seem to show that there is no such effect.

TABLE 1 TENSILE-TESTING RESULTS ON COUPONS TAKEN FROM DIFFERENT POSITIONS IN RUPTURED ETHYLENE-TANK HEAD

Mark	Yield point lb. per sq. in.	Ultimate strength lb. per sq. in.	per cent elongation	Per cent reduction in area	Remarks
	36,500	57,440	30.25	..	(a)
A-1	38,600	58,280	25.0	68.2	
A-2	36,750	59,950	32.5	62.6	
A-3	37,800	57,650	38.5	62.6	(b)
A-4	37,800	59,150	28.5	61.3	
B-1	43,650	58,700	33.0	64.7	
B-2	36,200	58,850	36.0	65.4	
B-3	36,300	55,750	39.5	63.5	(c)
B-4	41,400	60,100	35.5	62.8	
E-1	42,800	57,650	31.5	63.0	
E-2	40,800	59,250	32.5	59.8	(d)
E-3	49,500	63,800	28.0	58.8	
C-1	36,200	56,650	36.0	62.1	
C-2	37,400	60,900	34.0	59.1	
C-3	35,900	61,100	34.0	58.8	
C-4	35,500	58,500	38.0	60.1	
C-5	34,900	59,800	23.0	40.4	(e)
C-6	37,400	61,300	32.5	58.6	
C-7	32,400	59,600	34.0	59.8	
C-8	35,400	57,800	34.0	61.8	
C-9	37,900	60,800	37.0	61.3	
C-1-A	48,600	65,300	17.0	33.3	
C-2-A	50,900	71,100	8.0	18.75	
C-3-A	46,150	55,200	5.5	..	
C-4-A	43,700	61,200	6.0	5.22	
C-5-A	47,000	63,300	12.0	29.4	(f)
C-6-A	(x)	46,150	(x)	(x)	
C-7-A	48,000	65,100	25.0	39.3	
C-8-A	46,150	55,200	3.0	8.3	
D-1	53,400	64,100	29.0	57.8	(g)
D-2	45,700	62,150	26.0	57.0	
F-1	30,200	55,350	38.0	62.1	(h)
F-2	29,200	53,850	34.0	61.3	

(a) Mill test of head plate.
(b) Taken from head flange parallel with tank axis.
(c) Taken from head flange perpendicular to "A."
(d) Taken radially half-way between hole and knuckle.
(e) Taken from head close to weld and parallel with weld axis and outside tank surface.
(f) Taken from weld metal and parallel with direction of weld.
(g) Taken from head at manhole close to edge and outside.
(h) Taken from flange of manhole flange and as near edge as possible.
(x) Defect in test piece.

All these are within the limits of the specifications for steel in the A.S.M.E. Boiler Construction Code Section II.

In a number of instances, especially in the "D" and "E" test pieces, the yield point is considerably higher than in the case of the other pieces. The "D" pieces were taken close to the edge of the manhole and both the tensile strength and the yield point are higher

than the rest of the plate, while there is some decrease in the elongation and reduction of area. It should be remembered that the area from which these pieces were taken was heavily cold-worked by the stretching, and while, as will be referred to later, the microscope shows no particular evidence of this distortion, yet it is well known that stretching beyond the yield point produces the results given by these test pieces. Therefore, while there is no definite proof of the cause of these changes in physical properties, it is not

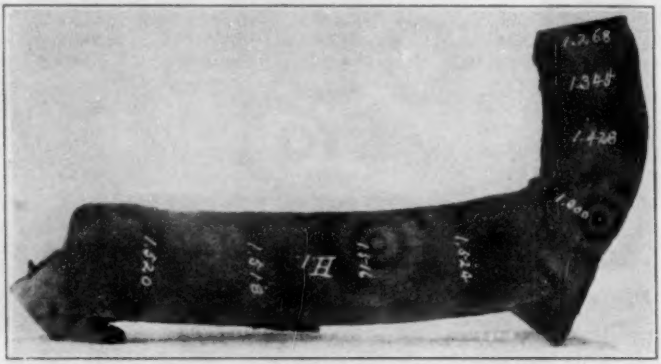


Fig. 13. Macroetching Showing the Thicknesses of the Manhole Flange at Different Positions and Showing Clearly That at the Knuckle of the Flange the Thickness Has Been Reduced by 0.2 in.

Fig. 14. Macroetching Showing the Thicknesses of the Manhole Flange at Different Positions

unreasonable to suppose that they are due in large part to the cold work, and it is perfectly safe to say that at least the material has not been injured.

The specimens taken from the weld metal show good strength and quite satisfactory properties, and are much better than many would expect. (These as well as the other test pieces are shown in Figs. 16, 17 and 18). While most of these samples appear to have broken approximately in the center of the reduced section of the tensile sample, a few of the breaks appear to have been initiated at some slight defect. It must not be forgotten that such defects are

not the same as those due to a serious lack of penetration or uniformly poor fusion, but that they are small and local and have but little effect on the strength of the structure as a whole. The author is not attempting to minimize, but to avoid exaggeration. It is also true that similar small defects are common in steel plate and that definite allowance is made for them in all standard specifications.

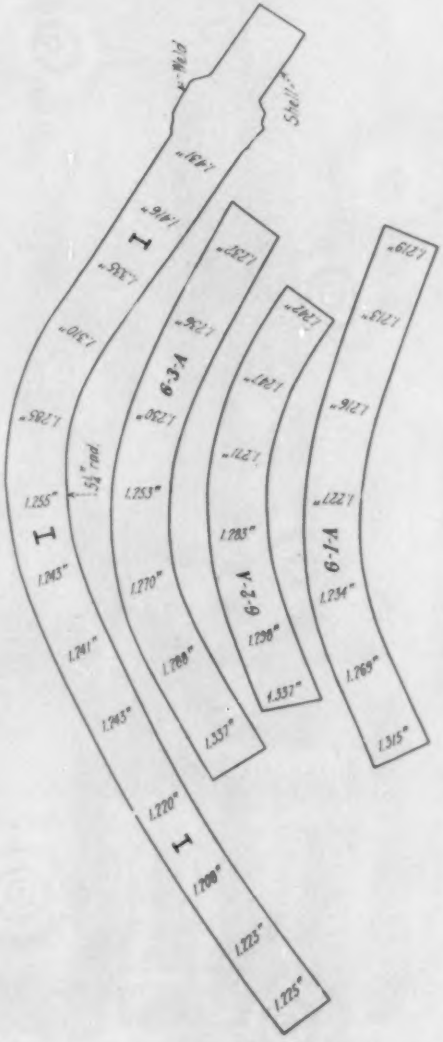


Fig. 15. Drawing Showing the Exact Curvature and Variations in Thickness of Test Samples Taken from Different Sections of the Tank Head at the Respective Positions Shown in Fig. 5

MICROSTRUCTURES

A few photomicrographs have been taken from the tensile-test-piece stubs. There is no serious difference in the structures except in the one taken from the weld metal, in which the structure is

coarser as would naturally be expected. The weld metal seems to have about the same carbon content as the base metal. It would also be expected that the metal just next the weld would be somewhat coarser, and this is the case, although the grain is finer than

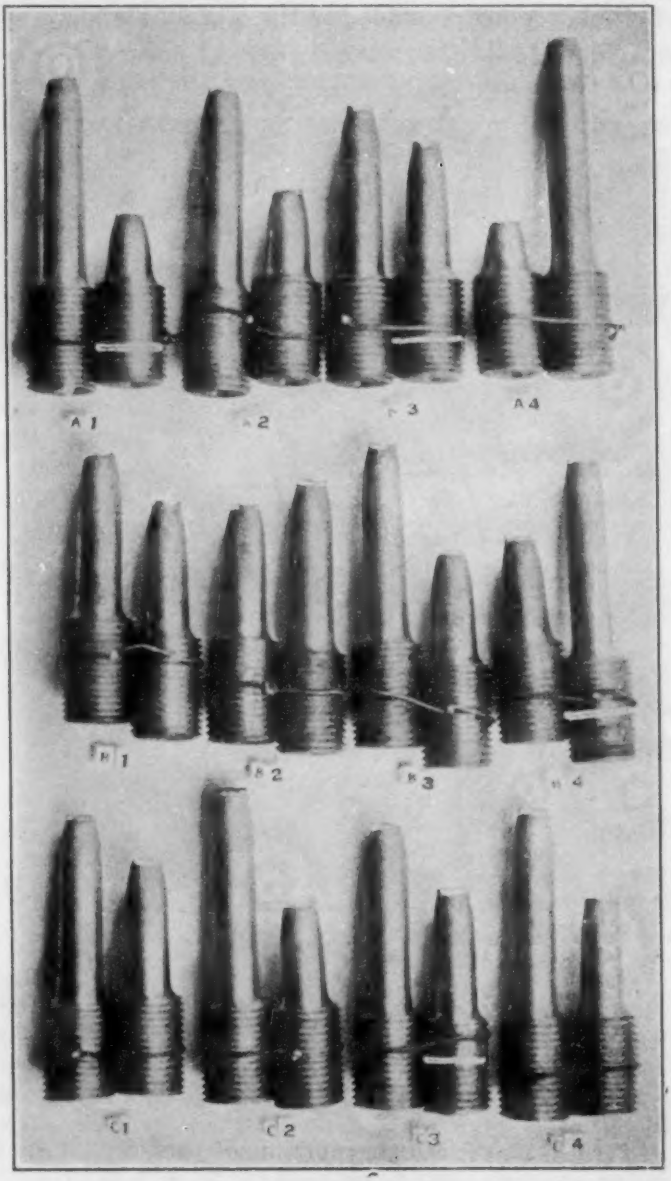


Fig. 16. Showing all the "A," "B," and "C" Tensile Samples After Testing

(The white lines shown on "A-1," "B-4," and "C-2" are shown in Figs. 20, 21, and 25 as micro sections, and in each of these cases are taken at right angles to the direction of testing.)

TABLE 2—RESIDUAL STRESSES AROUND MANHOLE IN TANK HEAD AND SADDLE PLATE IN FAILED HEAD OF ETHYLENE TANK

(Stresses in lb. per sq. in. between welds)

Location	Tank Head	Saddle Plate
J_1T_1	5,100 Tension	23,000 Compression
J_1T_2	9,000 Tension	15,100 Compression
J_1R_1	1,200 Compression	17,100 Tension
J_1R_2	16,500 Compression	10,200 Tension
J_2T_1	15,700 Compression	14,800 Compression
J_2T_2	16,500 Compression	13,900 Tension
J_2R_1	14,800 Tension	13,300 Compression
J_2R_2	12,200 Tension	10,700 Compression

Fig. 17. Photograph of Further Samples Which Were Tensile Tested and Whose Positions in the Tank Head Are Shown in Fig. 5

(The light lines shown on "E-1," "D-1," and "F-1" are the positions of the micro sections shown in Figs. 22, 24, and 26, and all are discussed under their respective figure numbers.)

might be looked for. The structure being quite regular, although having some patches in which the pearlite is distributed differently from what it is in most of the area, would seem to account for the lack of change in the physical properties.

CONCLUSIONS

1. The weld metal (nickel steel), shows ample strength and other physical properties.

2. The base metal next the weld was not injured by the heat of welding.

3. There was no significant difference in the physical properties of the metal in different parts of the head.

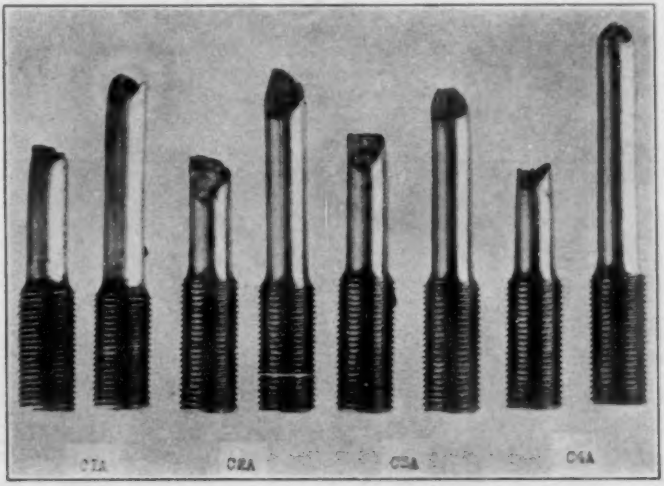


Fig. 18. Showing a Few of the Broken Tensile Samples Taken from the Weld Metal in the Manner Shown by the Circles in Fig. 6

(The ultimate tensile strengths of these samples were: C-1-A, 65,300; C-2-A 71,100; C-3-A, 55,200; C-4-A, 61,200.)

4. The welds were of good quality, and the fusion and penetration were satisfactory from a production standpoint.

5. There is no evidence that the 1000 lb. test pressure to which the tank was subjected affected the welds in any way.

Stresses in a Large Welded Tank Subjected to Repeated High Test Pressures*

T. W. GREENE[1], NEW YORK, N. Y.

During the test of this tank, strain-gage measurements were taken at all important points, and this paper deals with an analysis of the stresses and strains measured in the shell and head, especially those around the head knuckles and manhole opening. The magnitude of the stresses and cause of failure are discussed with

*Presented at a joint meeting of the Metropolitan Section and Machine Shop Practice Division of the A.S.M.E. with the New York Section of the American Welding Society, New York, January 4, 1927.

Abstracted from February issue of *Mechanical Engineering*.

[1] Linde Air Products Company.

[2] This head failure is described by S. W. Miller in The Design of Dished Heads of Pressure Vessels in *Mechanical Engineering*, Aug., 1926.

[3] For detail of design and construction, see paper by H. E. Rockefeller on Oxy-acetylene-Welded Construction of a Large High-Pressure Storage Tank.

the view of presenting engineering data on the effect of head knuckles and manholes on stress distribution, and to indicate the necessity of giving more consideration to the proper design of heads and manholes if high-pressure tanks are to be constructed to have the same factor of safety throughout as in the shell.

The results showed that the stresses measured in the shell agreed very closely with the theoretical. In the first test the agreement was not so close; moreover, the metal was permanently deformed by the pressure. This is due to bending stresses superimposed on the straight tensile stresses. The shell plate at the point measured appeared to be round and concentric, but due to irregularities in rolling and other causes, it is probably impossible to obtain exact concentricity in a tank shell. The pressure tends to round out these irregularities and force the shell to a true circle, thus setting up local bending stresses. The combined stress under the high pressure may cause the elastic limit of the material to be exceeded and the metal permanently deformed to iron out these irregularities.

Stresses Around Head Knuckles

The stresses around the knuckle of a tank are generally known to be high. Heads with a large radius of dish and small knuckle radius do not act as sections of spheres except at relatively low pressures. Under high pressures, such heads appear to act more as a dished plate supported at the rim. At the knuckle where there is an abrupt change in curvature and directional changes in the acting forces, high bending stresses are set up. The head under the internal pressure tends to protrude at the center of the tank and flatten or contract at the knuckle. Consequently very high strains are imposed in and near the knuckle, and if the elastic limit of the material be exceeded the head will take on a new shape, tending to assume that of an ellipsoid of revolution. This marked deformation of the knuckle and adjacent portions of the shell and head has been noted many times in tanks tested to destruction.

The results showed that the strains in a direction at right angles to the axis of the tank, that is, the hoop strains, change from tension on both sides of the knuckle to compression at the knuckle, the compression strains reaching a maximum at the center of the knuckle curvature. At operating pressure the strains are not high, but when the pressure is increased to two or three times the design load they become excessive, exceeding the elastic limit.

The strains around the manhole were extremely high. They were highest at the edge of the opening, but much less away from the edge, at two inches from the opening being a little over half that at the edge. But even at two inches away, they were greatly beyond the safety point.

On each successive application of the pressure there was further yielding of the metal around the manhole and an increase in the permanent set. The intensity of the forces acting around the

opening was either so large or the metal was so overstrained that continued yielding occurred. It was inevitable that the manhole head should fail.

SUMMARY

The results of the analysis of the deformation and distribution of stress in the shell and heads of this tank subjected to repeated high test pressures appear to warrant the following general conclusions:

1. The common formulas for designing the shells of ordinary pressure vessels give reasonably accurate determinations of the stresses.

2. Secondary stresses in the shell, manifested as superimposed bending stresses, are developed by irregularities in rolling, fabrication, or non-conformity of the shell to an accurate circular section. These affect the stress intensity, resulting in the combined stresses slightly exceeding the elastic limit in the first test, as shown by the strain measurements. These irregularities are either completely ironed out by high internal pressure, as shown by the close agreement of measured stresses with theory after the first pressure application, or their influence is materially reduced, resulting in lower stress intensity. The stresses under reapplication of pressure do not exceed the elastic limit and are proportional to the pressure. These results indicate that high test pressures improve the condition of the tank shell.

3. Very high bending stresses are imposed at head knuckles. A head with large radius of dish and small knuckle radius under high pressure appears to act more as a dished plate supported at the rim than as a section of a sphere, the basis of present design. Under the action of the internal pressure against the head, the knuckle tends to flatten out, setting up high compression hoop strains. The maximum tensile strains occur on the inside of the knuckle in a radial direction and result from bending in this direction as the knuckle radius is increased by the pressure. The results show that the stresses after the metal is deformed by a given test pressure are within the elastic limit unless this pressure be exceeded, in which case the deformation will continue until the head is readjusted to the higher pressure. It seems desirable to increase the corner radius, or redesign the head in closer conformity to the shape it tends to assume under internal pressure, in order to minimize the stress intensity and avoid the excessive and possibly dangerous tensile strains that may be developed at the inside of the knuckle.

4. The highest strains in a tank under internal pressure occur around the manhole. In some cases they are excessive or even dangerous at operating pressure, and in other cases may become dangerous at slightly higher pressures. The results from the first head with standard manhole construction show that because of the excessive strains around the manhole opening, continued yield-

ing occurred at this point on each application of a pressure slightly in excess of three times the design pressure. Head failure through the manhole such as occurred in this tank is inevitable under these conditions. Stress concentrations around holes or points of discontinuity, probably combined with bending action imposed by the manhole cover and head deformation, are the causes for such excessive strains being developed around manholes.

5. The strain measurements and test data of this investigation show that shells of pressure vessels designed and constructed in accordance with usual practices are entirely satisfactory and that welding can be safely used for fabrication, but it appears that the commonly used formulas for head design and manhole reinforcement are inadequate for high-pressure tanks. More consideration should be given to proper design of heads and manholes of pressure vessels, irrespective of the method of fabrication, if they are to be constructed to have the same factor of safety as in the shell.

Technical Question and Answer Column

Question

Can nickel be welded?

Answers

S. W. Miller, Union Carbide & Carbon Research Labs., Inc.

"The welding of nickel is rather difficult because of its tendency to absorb gases when melted and give them out when solidifying. The metal should not be heated any more than absolutely necessary to fuse it and the smaller the flame that can be used, the better. This means that preheating will help.

C. J. Holslag, Electric Arc Cutting and Welding Company.

"Nickel can be welded by the continuous arc or by the semi-arc. It is very liable to warping under the continuous arc, hence the advantage of the semi-arc in some cases. Nickel can be welded into cast iron or steel by either process. The same limitations prevail."

F. E. Rogers, Air Reduction Sales Company.

"Nickel is a difficult metal to weld owing to its attraction for oxygen when fused and brittleness at certain critical temperatures; also because of its heat conductivity which gives it a characteristic similar to that of copper. It is necessary to use from one to two sizes larger tip when welding nickel than on steel of the same gage. The fusion temperature is high, being about 2646 deg. Fahr., according to the Bureau of Standards determinations.

"The strength of nickel drops off at certain moderately high temperatures, there being two well-defined critical points in the temperature range at which the metal is quite brittle. These critical points are about 850 and 1750 deg. Fahr. Under some conditions

a welded seam will crack, especially if under strain as it cools down. Contraction stresses must be reduced to a minimum while cooling.

The weld should be mechanically worked before annealing. An attempt to anneal before mechanical working is likely to result in failure as welded nickel is brittle on the ascending temperature scales as well as when cooling, but if the weld can be mechanically worked the metal may then be rolled, drawn or otherwise worked."

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TORCHWELD EQUIPMENT CO.

224 No. Carpenter St. Chicago, Ill.

REGO

"LOWER OXYGEN PRESSURE"

Welding and Cutting Equipment

WRITE FOR CATALOG NO. 37

THE BASTIAN-BLESSING COMPANY

252 E. Ontario St., Chicago, Ill.

WE ANNOUNCE

That on and after February 21st, 1927, our Offices, Factory and Service Department will be

MOVED

to LARGER QUARTERS without interrupting sales or service

AT

515 West 29th St., New York City

Phone number will be the same Chickering 0996-7-8

K-G WELDING & CUTTING CO, Inc.

Weldite
Welding Rod
WELDITE G—No. 6 Coppered Finish for gas welding lays the metal down quietly, free from boiling, free from surface scum and floating white specks. The metal settles instantly when the torch is removed.
WELDITE E—No. 18 Green Surfaced for electric welding is the smoothest running electrode ever offered users of welding. Sold at the price of bare electrodes.
Products of the Research Department
Weldite
MANUFACTURED BY
CHICAGO STEEL & WIRE CO
103rd Street and Torrence Avenue CHICAGO

ACETYLENE IN PORTABLE CYLINDERS FOR OXY-ACETYLENE WELDING AND CUTTING

Do you understand our free loan cylinder plan? If not, we are glad to explain

Supplied in the following size cylinders:

10" x 30"—capacity 125 cu. ft.
12" x 36"— " 225 " "
12" x 44"— " 275 " "

Prompt and efficient service on any quantity through plants and warehouses and truck deliveries.

Commercial Acetylene Supply Co., Inc.
(Main Office) 80 Broadway, New York City, N. Y.

BRANCHES:
613 Trust Co. of Georgia Bldg., Atlanta, Ga.
80 E. Jackson Boulevard, Chicago, Ill.
553 Monadnock Bldg., San Francisco, Cal.

"Operator, please call Oxweld"

RIGHT at the end of the telephone. No matter where you live—Seattle, New Orleans, Atlanta or Boston—your telephone operator can call an Oxweld office.

Oxweld factories, sales offices and apparatus repair stations are spotted all over the country in every important industrial center.

Stocks of Oxweld generators, blowpipes, regulators and welding rods are carried at convenient points for prompt delivery. And Oxweld apparatus service men are everywhere.

Naturally such a development has not been spasmodic but steady and progressive. Naturally, too, it has been built on the confidence of Oxweld's customers in Oxweld equipment and service. For no such extensive growth is possible unless the product is worthy.

OXWELD ACETYLENE COMPANY

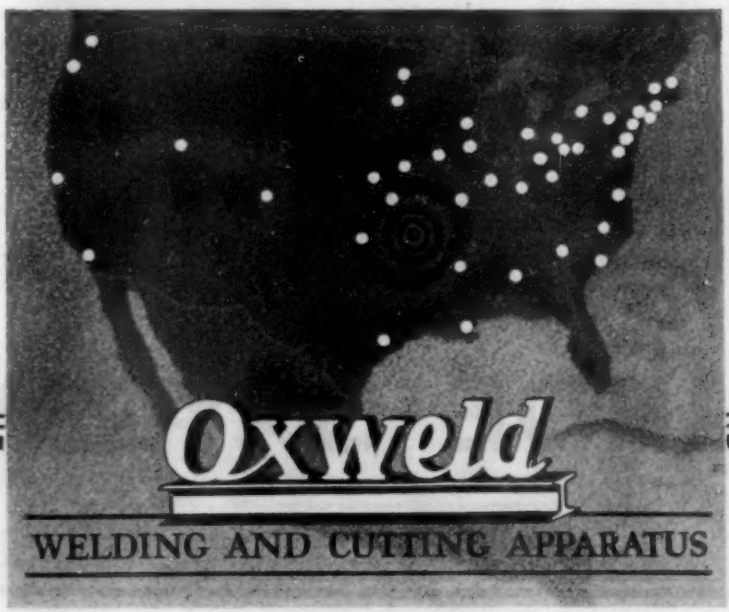
Unit of Union Carbide and Carbon Corporation

CHICAGO
3642 Jasper Place

LONG ISLAND CITY, N. Y.
Thompson Ave. and Orton Street

SAN FRANCISCO
1050 Mission Street

STOCKS IN 39 CITIES



That "personal equation" in welding —*

THERE IS a widely spread notion that welded joints are satisfactory only if you have an unusually good welder and that such welders are rare as jewels.

Let us straighten out this idea once and for all. Good welders are necessary, but with proper supervision good welders can be developed in a comparatively short time. Here, for example, are test records of single vee welds made with high grade soft iron wire by an average student during the first months of his employment:

Month	No. of Welds Tested	Average Tensile Strength
June, 1926	4	22,000
July	3	39,000
August	5	44,000
September	4	49,000
October	3	49,400

And when it is remembered that 47,000 is the average tensile strength of single vee joints with high grade soft iron wire, it can be assumed that a welder having a reasonable training period, working under proper shop conditions and competent supervision, would be able to turn out work meeting any reasonable specification.

If you exercise the same kind of care in purchasing or manufacturing welded equipment that is customary in purchasing machinery, and if you select the shop or the welder properly, you can rely on welded construction.

THE LINDE AIR PRODUCTS CO.
Unit of Union Carbide and Carbon Corporation
General Offices: Carbide and Carbon Bldg.
30 East 42d Street, New York
37 PLANTS · · · · 107 WAREHOUSES

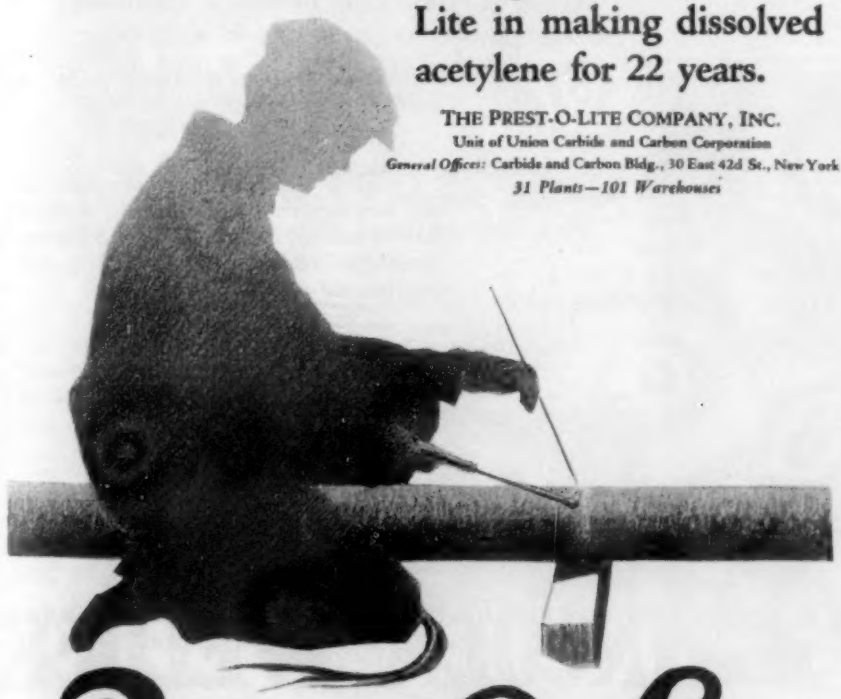
LINDE OXYGEN

* No. 3 of a series of advertisements on the engineering phases of oxy-acetylene welding and cutting. Send for the booklet entitled: "Engineering and Management Phases of Oxwelded Construction."

Experience

You who have had years of experience in manufacturing realize how experience is reflected in the product. Therefore you can appreciate the value of the experience of Prest-O-Lite in making dissolved acetylene for 22 years.

THE PREST-O-LITE COMPANY, INC.
Unit of Union Carbide and Carbon Corporation
General Offices: Carbide and Carbon Bldg., 30 East 42d St., New York
31 Plants—101 Warehouses



Prest-O-Lite
DISSOLVED ACETYLENE

Before you settle on the type of machine— get the users viewpoint

They say

(a new list in each issue)

"We are well pleased with speed and saving on a variety of steel work."

* * *

"Could not get along without it. Paid for itself first six months."

* * *

"Savings effected—too wide a range to specify."

* * *

"To give an itemized account of the savings that the Lincoln welder has saved us I fear would be rather tiresome for you before I could outline all of them."

* * *

"I have charge of the welder and am responsible for its operation and upkeep. So far it has not given me a minute's trouble."

Any Lincoln office below will put you in touch with a user near you whose experience covers many types of welders. Get his viewpoint based on experience.

"Stable Arc"

LINCOLN WELDER

The Lincoln Electric Co.

General Offices and Factory:
Cleveland, Ohio

Branch Offices
Baltimore
Boston
Buffalo
Charlotte, N. C.
Chicago
Cincinnati
Detroit
Des Moines
Grand Rapids

Branch Offices
Indianapolis
Milwaukee
Minneapolis
New York City
Philadelphia
Pittsburgh
Rochester
St. Louis

The Lincoln Electric Co. of Canada, Ltd., Toronto-Montreal
European Representatives: Allen-Liversidge, Ltd., London

Distributing agencies in all principal cities.

Exclusive Agencies with Stock:
Ft. Worth, Texas
New Orleans
Los Angeles
San Francisco

Returned to Service at a saving in time and labor

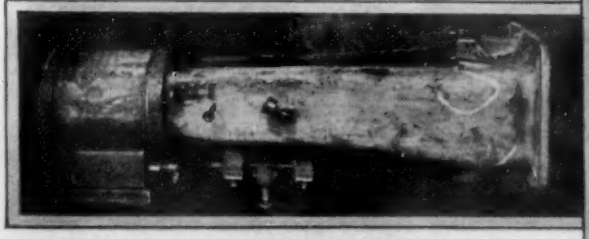
TOBIN Bronze Welding by the oxy-acetylene process made it possible to return this cracked engine casting to service as strong as ever in two hours and a half.

Because Tobin Bronze flows freely at 1650°F., complete dismantling for preheating in a furnace was unnecessary. The low temperature used also prevented distortion of the casting.

The great strength of the welds, together with the saving in time effected by the elimination of extensive preheating, makes Tobin Bronze Welding the logical method for many production operations as well as for repairs.

Tobin Bronze, manufactured exclusively by The American Brass Company, may be obtained from leading distributors of welding equipment and supplies.

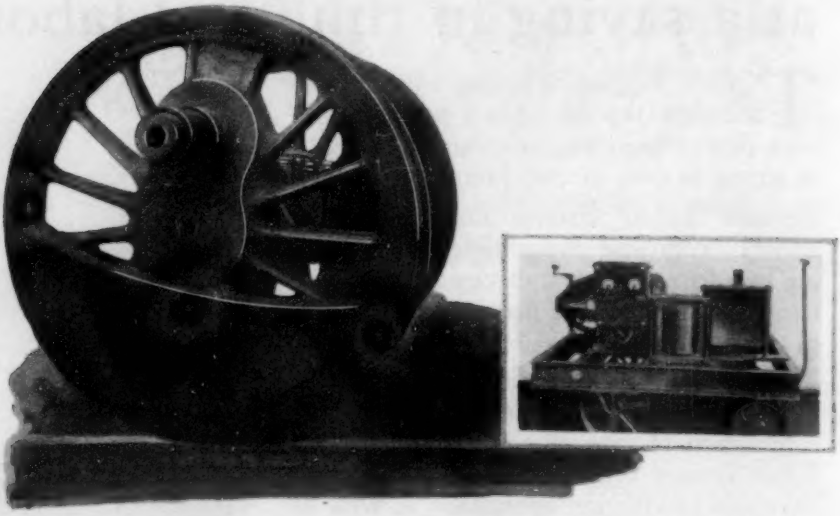
THE AMERICAN BRASS COMPANY
General Offices: WATERBURY, CONNECTICUT
Canadian Mill: ANACONDA AMERICAN BRASS LIMITED
New Toronto, Ontario



Cracked engine casting in position for Tobin Bronze Welding

As repaired with Tobin Bronze by the Oxy-Acetylene Process

TOBIN BRONZE
REG. U.S. PAT. OFF.
WELDING RODS
EXCLUSIVELY AN ANACONDA PRODUCT



Rolling Out of the Hospital

Driving-wheels roll out of a large railway repair shop better than new after a simple arc-welding operation performed by G-E Arc Welders.

When the two short spokes of the driving-wheels break, the wheels are rolled into the shop. Two men and a G-E Arc Welder begin work on them. The spokes are quickly welded and in the space between them is welded a 1¼-in. steel reinforcing plate.

The spokes are then stronger than when new. No locomotive driving-wheel thus repaired has ever broken in service. The complete job is done in 4 hours and very economically.

Complete details of this and other ingenious locomotive repairs performed with G-E Arc Welders will gladly be given upon request to your nearest G-E office.

General Electric furnishes to the Welding Industry:

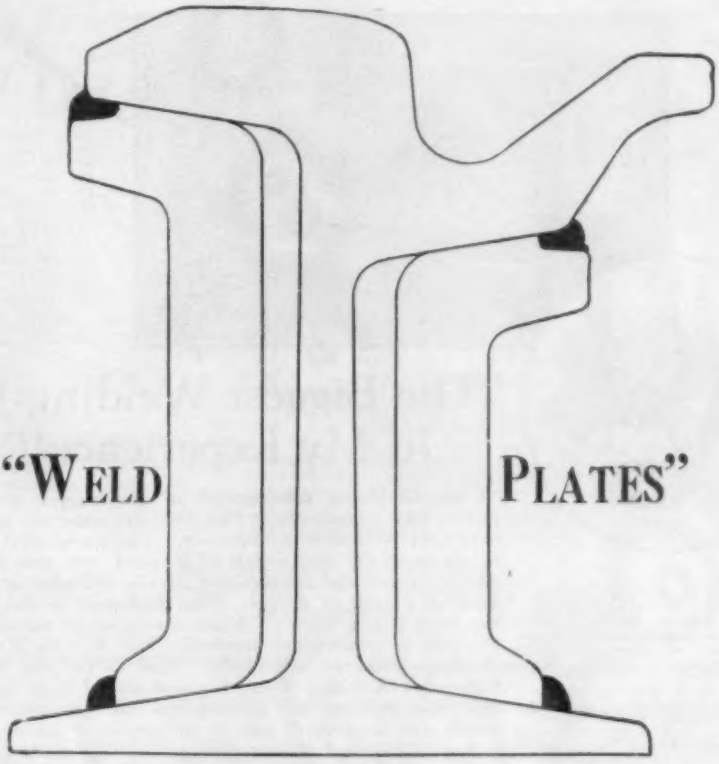
- WD Arc Welders—designed for one operator.
- Constant Potential Sets—for several operators
- Arc Welding Resistors—for mining and traction companies
- Automatic Welders—for repetition work
- Welding Electrodes

Bulletins available at your nearest G-E office.

530-17C

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y. SALES OFFICES IN PRINCIPAL CITIES



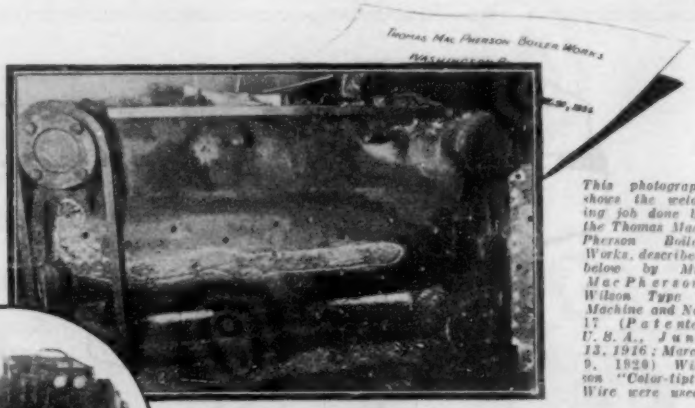
For EFFICIENT ECONOMICAL JOINTS

Do you believe in statistics? Rely on performance records? If so the performance records of the many "Weld Plates" now in use will convince you that they lead the bar-weld joints in efficiency and economy.

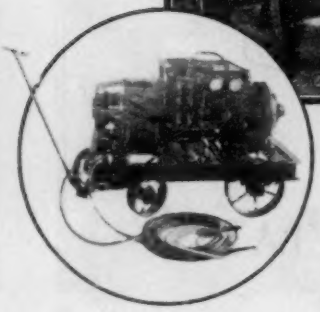
"Weld Plates" represent the most modern welding practice. They are the strongest and most up-to-date plates rolled especially for electric welded joints. Note the shape—the grooves for retaining plenty of weld metal along the upper edges—the wide contact areas at top and bottom—the suitability for the use of short bolts. A trial will convince you of their efficiency and economy.

THE RAIL JOINT COMPANY

165 Broadway, New York



This photograph shows the welding job done by the Thomas MacPherson Boiler Works, described below by Mr. MacPherson. Wilson Type S Machine and No. 17 (Patented U. S. A., June 13, 1916; March 9, 1920) Wilson "Color-tipt" Wire were used.



The above is a Wilson Type S Single-Operator, Motor-Driven Electric Welding Machine — designed for both production and repair work, and adapted for use wherever power is available. Its capacity is 25 to 300 amperes. Other Type S Machines include both single and two operator units — gasoline-engine-driven, belt-driven and motor-driven — portable and stationary. Capacities: 25-250, 25-300, 25-600 Amps.

"The Biggest Welding Job In My Experience!"

"I am enclosing photograph of the biggest welding job in my experience. The cylinder over all is 8 ft. long and 30 inches in diameter. The horizontal crack is about 6 ft. long; and that weld you see in the picture reaching up the end of the cylinder is 2 ft., making a total of 8 feet. The thickness of the cylinder wall is 1⅛ inches. I am very pleased to tell you the job is a complete success. The Wilson Welding Machine behaved splendidly. And as for the Wilson Color-tipt Welding Wire, I never would have tackled this job without it. As regards the procedure, the crack was first veed out to an angle of 45 degrees, holes drilled and ⅝-in. steel studs inserted at 1½-in. pitch. The cylinder was kept slightly hot."—T. MacPherson, Thomas MacPherson Boiler Works, Washington, Pa.

The biggest welding job in my experience! **An 8 ft. crack in a steam cylinder. A fussy job. But, experience pointed to the *sure* way—a Wilson Machine and the right grade of Wilson Wire.**

The right grade of wire for the metal, and perfect uniformity and flowing quality in each grade—that's Wilson "Color-tipt" Welding Wire! You can select just the right grade (analysis) for each weld—and every rod will be just like every other rod in the grade you select. Each grade is designated by a color, hence, "Color-tipt."

Are you profiting by the economies afforded by electric welding? And are you making possible the perfect weld? Use Wilson Machines and Wilson Wire—the right grade for the metal you're welding, of course—and the rest is up to the welder. There is a Wilson Welding Machine that meets *your* particular operating conditions—*your* particular industry. And there is a right grade (analysis) of Wilson Wire for the particular metal you are welding.

Send today for bulletins describing Wilson Welding Machines, and ask for sample of Wilson "Color-tipt" Welding Wire, indicating the kind of welding you wish to do.

WILSON WELDER & METALS CO. INC., WILSON BLDG., HOBOKEN, NEW JERSEY

WILSON

WELDING MACHINES AND WELDING WIRE

New Resistance Welding Economies and Efficiencies

The remarkable service, especially under severe conditions, that is given by

ELKONITE Welding Electrodes

can best be appreciated by the following plain comparison between Elkonite and previously used materials on identical jobs.

Operation	Previously Used Material	Elkonite
Radio Panels	100 welds	8,000 welds
Brass Radiator shells	16,000 welds	400,000 welds
Wire to heavy metal	300 welds	12,000 welds
Motor frame assembly	15 welds	400 welds
Wire to tin plate...	50,000 welds	2,500,000 welds (incomplete)
Galv. steel wire.....	15,000 welds	225,000 welds
Roller bearing assembly	24,000 welds	400,000 welds

Elkonite Welding Electrodes remain hard, *without mushrooming*, under red heat, great pressures, and heavy electric currents.
They have made the spot welding of BRASS, TINNED IRON, GALVANIZED IRON, and ALUMINUM commercially practicable.
Especially recommended for hot upsetting rivets electrically, facing clamps for rod welding, split dies for welding steel spokes to hub and rim of steel wheels, for flash and projection welding, and in many other applications where copper cannot be used on account of its softness.

In investigating the possibilities of Elkonite the Elkon Laboratories are at your service.

ELKON WORKS Inc.
A Subsidiary of P. R. Mallory & Co. Inc.
Weehawken, N. J.

Exclusive licensees under General Electric Co., patents dated May 28, 1925, and Sept. 1, 1925. Other patents pending to Elkon Works, Inc.

HOLLUP

WELDING WIRE AND SUPPLIES

ARE UNIFORM

Out of nearly two million pounds of Hollup Welding Wire shipped during 1926 not one pound was returned because of unsatisfactory performance.

WANAMAKER COATED ELECTRODES
REX PROCESSED BARE ELECTRODES
REX OXYACETYLENE WELDING RODS
REX WELDING ACCESSORIES

C. H. HOLLUP CORPORATION
3333 W. 48th Place, Chicago, Ill.

SWEDOX

WELDING RODS, WIRES and ELECTRODES

A Grade for Every Purpose

NONOX SWEDOX
LEKTROX SWEDOX
CASTOX
ARC CARBOX
GAS CARBOX
VANOX

TENSKOTE
DUCTKOTE
DUCTILOX
NICKOX
RAILOX

BRONZOX
BRONZKOTE
TOBIN BRONZE
MANGANESE BRONZE
MONEL METAL

STEELKOTE
LEKKOTE
CYLKOTE
MANKOTE
RAILKOTE

KROMOX
MANGANOX
ALUMINOX
DRAWN ALUMINUM
BRAZOX

TENSILOX
KROMKOTE
NICKOTE
VANKOTE
FLUXES

SEND FOR TESTING SAMPLE

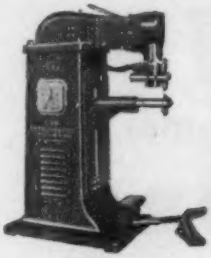
We want every welder in the country—big or small—to be convinced of the *specialized superiorities* of SWEDOX products. We know that a trial *will* convince you. Hence the free offer. Try SWEDOX on your next welding job at our expense.

CHICAGO, ILL.
4545 S. Western Blvd.
Phone:
LaFayette 8500

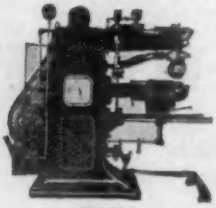
Central Steel & Wire Company

DETROIT, MICH.
5001 Bellevue Ave.
Phone:
Lincoln 6780

"We Ship the Same Day"



SPOT



SEAM

ARC

For Production
Electric Welding
Machines

Gibb Welding Machines Company

Bay City, Michigan

New York—Philadelphia—Cleveland—Cincinnati—Detroit—Buffalo
Chicago—St. Louis—Los Angeles—Toronto—Montreal

Roebling

Welding Wire gives satisfactory service and demonstrates its efficiency and reliability. Exacting tests have proven that it possesses those qualities essential to good welding. Be sure your bundles bear this tag.

BOUND VOLUMES—1926

NOW READY

A number of copies of the Journal of the American Welding Society for the year 1926 have been bound in attractive book form. Copies may be purchased by members at $5.00 per copy; non-members $10.00 per copy.

THERMIT WELDING

For heavy welding operations
in all fields

Railroad Industrial Marine

METAL & THERMIT CORPORATION
120 Broadway, New York
Pittsburgh Chicago Boston S. San Francisco Toronto

Why Experiment?

Torches
Regulators
Generators
Compressors
Manifolds
Preheaters
Paint Sprays
Carbide Lights
Catalog 54?

SINCE the infancy of the industry, expert engineers and skilled workmen have maintained the predominance of Milburn Equipment.
Its acceptance as standard equipment by large industrials, railroads and Government Departments the world over exemplifies Milburn leadership.

THE ALEXANDER MILBURN CO.
Baltimore, Md.

With a welding current range of 75 to 450 amperes, UNA Welders are equally satisfactory from the welding of the thinnest metal sections to the heaviest structural steels and castings. Either the metal arc or carbon arc process may be used with these welders.

UNA WELDING AND BONDING COMPANY
CLEVELAND, OHIO

Welding Processes
Welding Rods

UNA

A.C.-D.C. Welders
Welding Supplies

"Here is wire you can *depend upon*"

Experience has taught thousands of welders to look upon Page quality as a matter of course—something to be depended upon at all times. They know that when they choose a particular wire or electrode to do a certain job—that it will produce a weld of similar properties to the base metal, lower production costs and eliminate spoiled work.

The reason lies in the Page process of manufacture. First, all raw material is analyzed to assure uniformity. Second, all Page wire and electrodes are processed to meet the exact requirements of the work to which they will be placed. Third, they are shop tested to assure working qualities under actual job conditions. Fourth, each piece is plainly marked for identification.

Prove these facts for yourself. Write today for a sample of wire and further information. No obligation.

PAGE STEEL AND WIRE COMPANY

An Associate Company of the American Chain Co., Inc.

Bridgeport, Connecticut

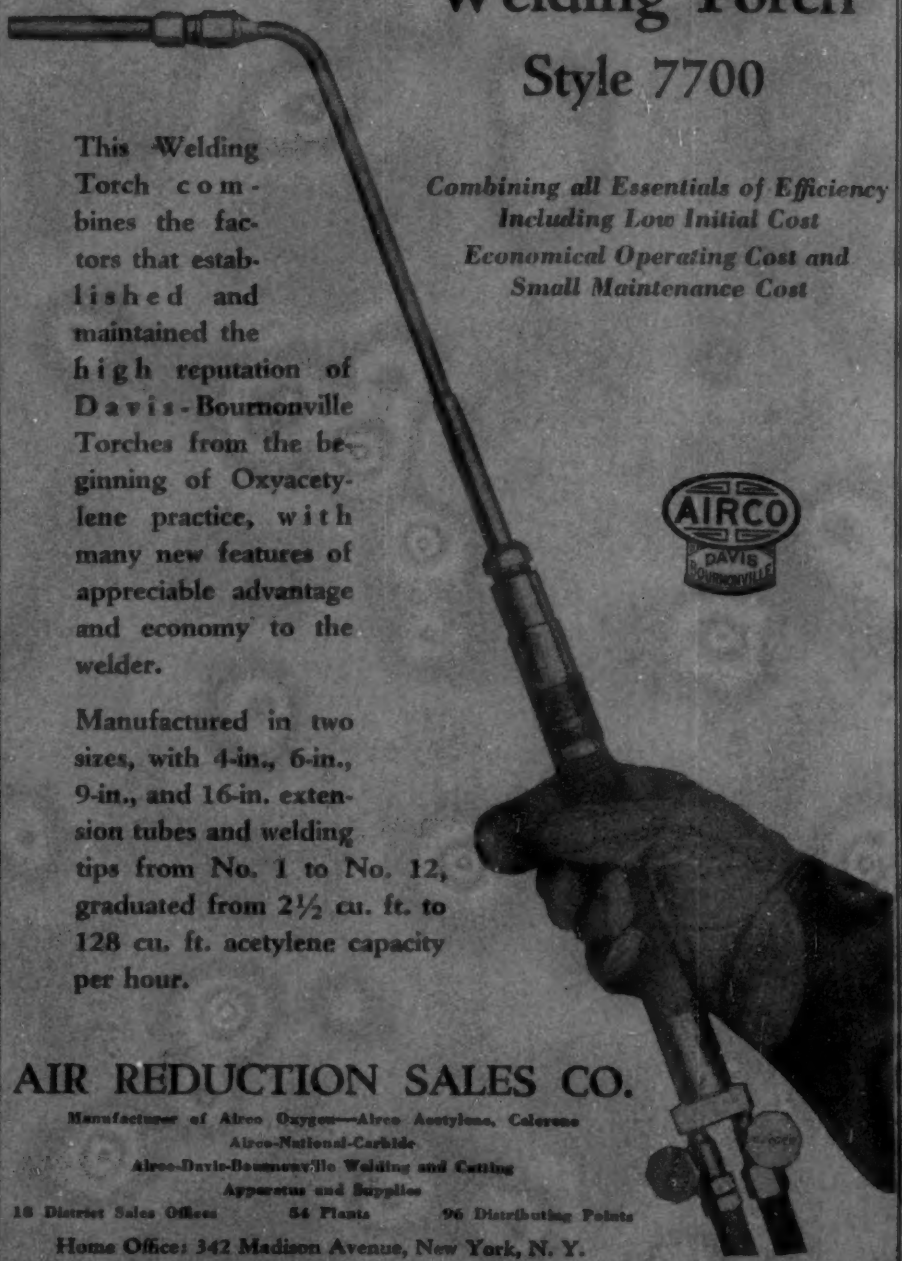
District Sales Offices: Chicago New York Pittsburgh San Francisco

PAGE-ARMCO

PROCESSED

Welding Wire *and* Electrodes

An Airco-Davis-Bournonville Welding Torch Style 7700



Combining all Essentials of Efficiency
Including Low Initial Cost
Economical Operating Cost and
Small Maintenance Cost

This Welding Torch combines the factors that established and maintained the high reputation of Davis-Bournonville Torches from the beginning of Oxyacetylene practice, with many new features of appreciable advantage and economy to the welder.

Manufactured in two sizes, with 4-in., 6-in., 9-in., and 16-in. extension tubes and welding tips from No. 1 to No. 12, graduated from 2½ cu. ft. to 128 cu. ft. acetylene capacity per hour.

AIR REDUCTION SALES CO.

Manufacturer of Airco Oxygen—Airco Acetylene, Coleneo
Airco-National-Carbide
Airco-Davis-Bournonville Welding and Cutting
Apparatus and Supplies

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